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FEASIBILITY STUDY
PACIFIC SOUND RESOURCES
MARINE SEDIMENTS UNIT
SEATTLE, WASHINGTON

Prepared for

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SECTION 1

INTRODUCTION

1.1 REPORT PURPOSE AND ORGANIZATION

This Feasibility Study (FS) report provides a summary of findings and remedial alternatives for contaminated sediment within the Marine Sediments Unit (MSU) of the Pacific Sound Resources (PSR) Superfund site. The remedial actions are based on sediment chemistry data obtained in the Remedial Investigation (RI) of the MSU site. An RI/FS for the upland property (Upland Unit) addressing groundwater and non-aqueous phase liquid (NAPL) was produced under separate cover by the Port of Seattle (**RETEC 1997**) in cooperation with EPA. Early actions implemented by the Port and approved by EPA resulted in removal of contaminated soils and control of the migration of shallow groundwater and the lighter fractions of NAPL in the Upland Unit to the extent practicable.

The purpose of this FS report is to provide EPA, other interested agencies, and the general public with findings of the sediment feasibility study and recommendations regarding contaminated sediment cleanup for their review and comment. This document was written in accordance with EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (EPA/S40/6-89/004).

This document presents the need and purpose of the project, identifies sediment contaminants of concern, discusses applicable or relevant and appropriate requirements (ARARs) and site risks to determine cleanup goals that meet the Washington State Sediment Management Standards (SMS). It also identifies and screens technologies capable of remediating sediments to these goals. Based on these goals, remedial action alternatives were developed and evaluated. Finally, based on a comparative analysis, a preferred alternative is selected for cleanup of the PSR MSU.

The FS report is organized into six sections with accompanying appendices and maps. **Section 1** describes the physical, historical, and ecological setting of the MSU and vicinity, and discusses sediment contaminant sources. **Section 2** summarizes the nature and extent of sediment contamination, and develops numerical site cleanup goals based on ARARs and site risks. **Section 3** identifies, discusses, and screens potential remedial technologies to determine their viability for MSU site remediation. **Section 4** assembles these technologies into remedial action alternatives. **Section 5** provides an evaluation of these alternatives against seven criteria to determine their overall performance and a comparative analysis to determine their relative ranking. **Section 6** presents the preferred remedial action alternative.

1.2 PROJECT PURPOSE AND NEED

As demonstrated in the remedial investigation report, sediments in the PSR MSU contain PAHs at concentrations that represent a threat to the health of humans who may consume fish caught in the vicinity of PSR and aquatic receptors that may reside or feed in the area. The purpose of the proposed cleanup action is to prevent the exposure (either directly or via ingestion of contaminated food) of the threatened receptors to the sediment-bound chemicals of concern to the extent practicable. The SMS provide the range of chemical concentrations in sediment that should result in minimal impacts to benthic invertebrates and are used as the basis of each alternative developed and evaluated in this FS.

Additional site-specific features or constraints will be considered when determining the effectiveness of a given remedy. These features or constraints include the geotechnical stability of the shoreline and areas to be capped or used as a disposal site, the depths where contaminated sediments occur (e.g., a large area of the site is deeper than -100 feet mean lower low water [MLLW], with a portion deeper than –200 feet MLLW), and the potential for recontamination from both groundwater discharge from the Upland Unit and releases that may occur during sediment removal and disposal. See **Section 4** for a more detailed discussion of these issues.

Additional issues potentially affecting a remedy for the PSR MSU include water-dependent uses. The MSU is located in an area of Elliott Bay that is used as an anchorage for large ships and barges accessing the Duwamish River and its waterways. An active bulk materials shipping facility [Crowley Marine Services (CMS)] is adjacent to the MSU, necessitating access and adequate navigational depths (20 to 24 feet of water) in the MSU. The MSU is also part of the usual and accustomed fishing grounds for both the Muckleshoot and Suquamish tribes. In addition, all shorelines within Elliott Bay provide migratory corridors for salmonids; Puget Sound chinook salmon are currently proposed for listing as threatened under the Endangered Species Act (50 CFR Part 226).

To incorporate these unique constraints in the evaluation of alternatives, a series of FS site-specific criteria were developed in consultation with the U.S. Army Corps of Engineers, Washington State Departments of Ecology and Natural Resources, and Trustee agencies and tribes. The criteria include the following:

An effective and appropriate alternative must:

- Minimize impacts to tribal, recreational, and/or commercial fisheries
- Minimize impacts to current water-dependent industries
- Complete actions within an acceptable time-frame (less than 3 years)
- Not jeopardize threatened or endangered (listed or proposed) species
- Provide a minimum design life of 30 years (for engineered components)

- Maintain geotechnical stability of shoreline
- Minimize impacts to water quality during the remedial action
- Maintain the physical integrity of in-water constructed features
- Result in a human health excess cancer risk of less than 1 in 10,000 and a noncancerous hazard index of less than 1.0.

1.3 SITE BACKGROUND

Background information on the Upland and Marine Sediment units was presented in detail in the Summary of Existing Information and RI/FS Approach Technical Memorandum (**WESTON 1995**), the RI/FS Work Plan (**WESTON 1996**), and the draft MSU RI Report (**WESTON 1998**). The following sections summarize the information presented in those reports.

1.3.1 Site Location and Upland Use History

The PSR Upland Unit was a wood-treating facility located on the southern shore of Elliott Bay (**Figure 1-1**). The original facility was a pile-supported structure over intertidal and subtidal bottom lands that was expanded over 25 acres. The upland property is bounded to the north by Elliott Bay, and on all other sides by the Port's newly constructed intermodal yard and container shipping facilities (of which PSR is now part).

The PSR MSU encompasses approximately 150 acres of Elliott Bay adjacent to and offshore of the Upland Unit. Elliott Bay has been extensively developed for urban, port, and industrial land uses; the area surrounding the site has many facilities linked to water-dependent industries.

Historical operations at the Upland Unit consisted exclusively of wood preserving between 1909 and 1994 (**RETEC 1997**). Preservatives most commonly used in the wood-treating operation included creosote and creosote/fuel oil mixtures, pentachlorophenol (PCP), and Chemonite (also known as AZCA, a mixture of ammonical zinc, copper, and arsenic). Zinc meta-arsenate, chromated zinc chloride, Wolman salts (containing fluoride, chromium, arsenic, and phenol), and Pyresote (made of zinc chloride, boric acid, ammonium sulfate, and dichromate) have also been used on the site (**RETEC 1997**). The draining of retorts, transfer of newly treated wood products to various areas of the site, spills, leaks and storage of treated wood products were primarily responsible for the contamination of soil and groundwater in the Upland Unit. Areas associated with the retorts, transfer tables, and preservative storage tanks in the northern half of the site represented the areas of greatest chemical contamination prior to initiation of upland cleanup activities. **Figure 1-2** shows the locations of excavated source areas at the site. Direct discharge or disposal of process wastes and indirect transport (surface water runoff, soil erosion) were the most likely sources of contamination in the MSU.

1.3.2 Current and Planned Future Use

The Port of Seattle has redeveloped the Upland Unit as an intermodal railyard and container shipping terminal. This facility includes railroad tracks, buildings, and underground utilities (**RETEC 1997**). The CMS property west of the site will continue operation as a barge transport facility for bulk materials.

As part of the Port's site redevelopment, a public access corridor, including an elevated walkway, bike path, playground, and viewing tower, have been constructed along the northernmost portion of the site. The main pier at PSR has been retained as a public viewpoint. However, both the shoreline and the pier are fenced to limit access to the shoreline and Elliott Bay, which is currently the site of many water-dependent and recreational activities. Such activities in the vicinity of the site are limited to boat access only. The nearest public boat launch facility is at Don Armeni Park, approximately 0.5 mile northwest of the site.

Elliott Bay, including the area in the vicinity of the PSR site, is also part of the usual and accustomed fishing grounds of the Muckleshoot and Suquamish tribes. Tribal members engage in net fishing for salmon. In addition, the Tribes have federally guaranteed treaty rights to gather shellfish in Elliott Bay. The usual and accustomed fishing areas for the Muckleshoot and Suquamish Tribes are shown in **Figures 1-7 and 1-8**, respectively.

1.3.3 Upland Cleanup Actions

1.3.3.1 Facility

In the Upland Unit, all structures, with the exception of one large foundation that was not a source of contamination, have been demolished. Several additional cleanup actions have been completed, including removal of the woodwaste fill in the southern portion of the site, installation of a subsurface containment (slurry) wall and light nonaqueous phase liquid (LNAPL) recovery trench, installation of a deep stormwater sewer system, addition of fill to elevate the site grade, and placement of a surface cap over the site. Details regarding each of these early actions are provided in Implementation Plans (**RETEC 1994c** and **1995**) and the Upland RI (**RETEC 1997**) and are briefly addressed below.

A physical containment barrier was installed in early 1996 to prevent LNAPL migration to Elliott Bay and to dampen tidal influence at the site. The slurry wall is 1,200 feet in length and its depth varies from 32 to 51 feet below ground surface (bgs) (**RETEC 1997**). The LNAPL recovery trench was installed in conjunction with the barrier to recover any product migrating towards the bay. To date, recovery equipment has not been installed because no LNAPL has collected in the trench (**RETEC 1997**). The locations of the slurry wall and LNAPL recovery trench are shown in **Figure 1-2**.

A low-permeability asphalt cap was constructed over a layer of clean fill placed at the site to: (1) prevent direct exposure of site personnel to contaminants in the surficial soil, (2) prevent the off-site migration of surficial soils via surface runoff, (3) minimize impacts to groundwater by limiting infiltration of surface water and subsequent leaching of contaminants to the groundwater, and (4) support site development. Capping was completed in 1997 [**RETEC 1998 (pending)**]. The cap area is shown in **Figure 1-3**.

An RI/FS to determine the extent of groundwater and NAPL (both light and dense) contamination and formulate cleanup options has been completed. As part of this work, groundwater and surface and subsurface soils have been tested to determine the distribution of NAPL and dissolved contaminants in groundwater throughout the site (**RETEC 1997**). Several treatability studies for groundwater have also been conducted. Additional completed work includes tidal fluctuation studies and flow estimates to assess the performance of the slurry wall (**RETEC 1997**).

As part of the Upland Groundwater and NAPL RI, several recovery wells were installed to test the feasibility of passively recovering dense nonaqueous phase liquid (DNAPL). For wells yielding sufficient testing volumes, testing was conducted during the first six months of 1996 (**RETEC 1997**). Although NAPL has been present in several wells, there has been a general trend of decreasing production in wells where recovery of product has been conducted.

The Upland RI and design of the early cleanup actions, as described, have been completed. As a result of these early cleanup actions, potential health and environmental risks related to site contaminants have been significantly reduced (**RETEC 1997**). The effectiveness of the early actions in minimizing releases of site-related contaminants to Elliott Bay will continue to be monitored at the completion of all cleanup actions.

1.3.3.2 Longfellow Creek and Overflow Channel

The Longfellow Creek overflow channel borders the western-most boundary of the current Port facility. Historically, Longfellow Creek flowed north along the southwestern edge of the site into Elliott Bay. The creek has since been diverted and currently flows into the West Waterway of the Duwamish River. The Longfellow Creek overflow channel, which acts as a local stormwater drain, flows through a closed culvert (in the former creek channel) and discharges near the CMS barge facility west of the PSR property. Because the overflow channel potentially receives groundwater from the site, as well as stormwater and other runoff, the Port chose to clean out the culvert before initiating a groundwater monitoring program. All in-line sediment was removed from the pipe from the Birmingham Steel site to the pipe outlet. An additional 25 cubic yards of contaminated sediments were removed from the shoreline at the outfall. Birmingham Steel maintains a current NPDES permit to discharge stormwater to the Longfellow Creek overflow channel (**Stetz 1998**).

1.4 PHYSICAL SETTING

The physical setting of the Upland Unit and MSU is presented in detail in the MSU RI Report (**WESTON 1998**). The following sections summarize the information from that report.

1.4.1 Upland and Shoreline Features

The PSR Upland Unit is built atop fill material 20 to 45 feet thick. Buried wood and concrete bulkheads constructed to contain the fill material, control erosion, and protect equipment from marine tides, are present in upland portions of the site. Filling events occurred from 1927 to 1974 and are described in the MSU RI Report (**RETEC 1997**). The origin and chemical characteristics of the fill material are largely unknown. Some known fill materials include dredge spoils from the Duwamish River, soil from Beacon Hill, sawdust, peat material, and concrete riprap. In general, the texture of the fill is sandy with varying mixtures of clay, silt, and gravel.

The shoreline of the PSR Upland Unit consists primarily of rock and concrete riprap. Various fill materials, including bricks and steel cable, were observed along the bank during a 1994 shoreline reconnaissance (**WESTON 1994a**). Three wooden piers, which form the Main and West slips, extend into the central and western portions of the MSU. As part of the Port's redevelopment of the site, one of the three piers has been repaired for use as a public viewing platform. It is anticipated that the remaining piers will be removed to facilitate cleanup. Two small pocket beaches exist at the foot of the riprapped bank in the Main and West slips (depicted in **Figure 1-2**).

1.4.2 Geology

The PSR Upland Unit is located at the north end of the Longfellow Creek overflow channel physiographic division of the Puget Sound Basin (**RETEC 1994a**), on former mudflats and sloughs associated with the original Duwamish River delta. Site stratigraphy is generally characterized by fill overlying recently deposited (post-glacial) alluvial and estuarine soil. Borings have found low-permeability estuarine deposits, typically to the depth of the boring (up to 135 feet bgs) (**RETEC 1997**). Bedrock is estimated to occur 340 to 680 feet bgs, although none has been encountered to date (**RETEC 1997**).

1.4.3 Hydrogeology

The Upland Unit lies within an area influenced by the marine waters of Elliott Bay, estuarine waters of the Duwamish River, and fresh surface water. The hydrogeology is influenced further by the material properties and spatial distribution of the various on-site soil units and bulkheads.

The hydrogeology of the Upland Unit is characterized by a single unconfined shallow aquifer within the fill and alluvium. The water table is present at an average depth of approximately 6 feet bgs, but the depth to groundwater varies with the amount of rainfall and the tidal cycle. Investigations indicate that no continuous impermeable layer exists in the upper 150 feet beneath the site (**RETEC 1997**). However, the estuarine sediment unit and associated deltaic deposits below the fill have a relatively lower permeability compared to the overlying fill.

Groundwater recharge in the area occurs as a result of stormwater infiltration from the site, as well as from upland areas to the south. Groundwater below the Upland Unit is influenced by infiltration of estuarine waters from Elliott Bay; however, infiltration has been significantly reduced by the slurry wall (**RETEC 1997**). Stormwater infiltration on the site has been precluded by the construction of the surface cap covering the site. The interface between fresh and saline water is typically located between 25 and 30 feet bgs in the northern half of the upland site.

The overall movement of groundwater in the vicinity of the site is in a northerly direction toward Elliott Bay. Local groundwater flow in the northern portion of the site is north and northwest, while flow in the southern part of the site is mainly west toward the Longfellow Creek drainage. Historically, groundwater gradients were strongly affected by tidal fluctuations. Tidal influence was strongest in fill materials and decreased significantly in native soils. Tidal fluctuation has been significantly reduced in shallow upland wells following construction of the slurry wall (**RETEC 1997**). High tides may also periodically result in temporary reversal of groundwater flow directions. The heterogeneity of fill material and resulting hydraulic conductivity and the presence of buried bulkheads complicate on-site groundwater distribution patterns. Groundwater discharge to the bay likely occurs via shoreline diffuse flow through nearshore sediments (**RETEC 1994a**). Groundwater seeps (as evidenced by the presence of petroleum sheens) in the intertidal zone were observed during a 1994 shoreline reconnaissance (**WESTON 1994a**) prior to slurry wall construction; however, no seepage has been observed since wall placement.

1.4.4 Regional Meteorology

The regional climate is a mid-latitude, West Coast marine type. Most air masses affecting the region originate in the Pacific Ocean. Prevailing onshore winds slow rapidly upon landfall. The resulting convergence leads to ascent of the air masses and enhanced precipitation. The surrounding mountains further enhance precipitation. The region where the site is located typically receives between 35 and 40 inches of rain per year, and is characterized by a rainy season (October to March) and a dry season (April to September).

The maritime weather systems have a moderating effect on annual temperatures. Winter daytime temperatures are typically between 40 and 50 degrees Fahrenheit, while nighttime temperatures range in the 30s. Summer daytime temperatures are typically between 70 and 80 degrees Fahrenheit with nighttime lows in the 50s. Extremes in temperature are associated with disturbances in the normal weather pattern and are usually brief.

1.4.5 Upland Surface Water Features

No surface water bodies are located on the PSR Upland Unit, although localized flooding has been documented during periods of heavy rainfall. As described in **Section 1.3.3.2**, the Longfellow Creek overflow channel, which flows via culverts through the former stream channel and receives local surface and groundwater, discharges to Elliott Bay via the Longfellow Creek outlet located directly west of the PSR property **(RETEC 1997)**.

1.4.6 Elliott Bay and Duwamish River Estuary

The MSU encompasses approximately 1,600 feet of constructed shoreline along Elliott Bay. Elliott Bay covers approximately 8 square miles, with extensive industrial, commercial, and residential development along much of its shoreline. Urban and industrial development along the shore includes recreational beachfront and boat moorage facilities, shipyards, heavy and light industrial operations, and numerous shipping terminals.

The mouth of the Duwamish River's West Waterway is located approximately 0.3 mile east of the PSR site. This waterway channels the majority of downstream flow to Elliott Bay. The lower 6 miles of the river, including its confluence with the bay, form the Duwamish River estuary. Development throughout the estuary is similar to that along Elliott Bay, consisting primarily of light and heavy industrial operations, marinas, and commercial operations.

1.4.6.1 Bathymetry

Bathymetric contours and slopes for the MSU are shown in **Figure 1-4** (based on a 1995 NOAA survey). Depths range from intertidal to greater than -255 feet MLLW. Natural intertidal areas are limited to two small pocket beaches at the head of the West and Main slips. Bathymetric contours indicate that the steepest slopes are nearshore (shoreward of approximately -130 feet MLLW), ranging from 18 to 21 percent. Two relatively flat areas (with slopes ranging from 0 to 6 percent) exist directly offshore of the CMS terminal at -40 feet MLLW and offshore of the Lockheed facility. At depths greater than -130 feet MLLW, slopes gradually decrease from 15 to 3 percent as distance from shore increases.

1.4.6.2 Currents and Tides

Elliott Bay experiences mixed semidiurnal tides with a maximum recorded tidal range of 14.8 to -4.6 feet MLLW. Because the PSR site fronts Elliott Bay, this range likely reflects the range of conditions at the site.

Surface currents within Elliott Bay are influenced by Duwamish River flows, tides, and prevailing southwesterly winds. The surface water mass frequently travels counter-clockwise along the eastern shore, but exhibits a fair amount of variability. Bottom currents also vary, but tend to follow a clockwise gyre **(WESTON 1994b)**. Both bottom and surface currents are typically weak with a mean speed less than 0.3 foot per second (**NOAA 1981, EVS 1996**). The configuration of the shoreline containing the Main and West slips and the area adjacent to the former storage tank area likely cause localized eddies to form to the west and east of these features.

1.4.6.3 Water Quality

Elliott Bay is designated as a Class A (excellent) waterbody [WAC 173-201A-140(8)]. This classification designates general characteristic uses, including domestic, industrial and agricultural uses; fish and shellfish migration, rearing, spawning, and harvesting; recreation; commerce; and navigation. The Duwamish River is designated as a Class B (good) river [see WAC 173-201A-130(37)], with slightly limited characteristic uses.

1.4.6.4 Sediment Sources and Transport

The main source of sediment to Elliott Bay and the MSU is from loadings carried by the Duwamish River (**WESTON 1994b**). However, the amount of sediment transported to the southern portions of Elliott Bay in the vicinity of the MSU has been substantially reduced by anthropogenic changes to the river (construction of dams and sediment retention basins) and extensive shoreline stabilization along the river and bay shorelines.

Estuarine conditions in the lower river cause the majority of the suspended river sediment to initially settle there and at the mouth of the West Waterway (**WESTON 1994b**). However, suspended sediment that enters Elliott Bay during peak flows as part of the buoyant freshwater surface plume can be transported towards the Seattle waterfront by southwest prevailing winds. Recent work by **GeoSea (1994)** suggests that this sediment may be entrained in the dominant clockwise gyre that forms near the bottom and transported as bedload back towards the Duwamish River, along the PSR shoreline to the Duwamish Head, and then into deep canyons near the entrance of the bay. Historical biological data collected by **Harmon and Serwald (1978)** tend to support the prevalence of this bottom clockwise current, based on the distribution of typically nearshore estuarine fauna in deeper marine sediment to the west and north of the Duwamish River mouth.

Sediment transport in the MSU is likely to be seasonal because river flow and subsequent sediment loads vary seasonally. Sediment tends to accumulate in nearshore environments during the summer months and erode during winter months because of the differences in direction and magnitude of prevailing winds, currents, and wave action. Based on the presence of fine-grained sediments in the slips along the shoreline, these nearshore areas are either depositional areas, or areas of no net loss. Ship traffic in nearshore areas further modifies these patterns and may cause sediment resuspension in localized areas. In general, nearshore areas tend to be coarser-grained than deeper, offshore areas, indicating there may also be downslope migration of finer-grained materials.

1.4.6.5 USGS Bottom Surveys

A study of substrate characteristics in the MSU was conducted by the U.S. Geological Survey (**USGS 1996**), in which potential areas of non-native materials were mapped using side-scan sonar. The results of the side-scan sonar survey are depicted in **Figure 1-5**. Comparisons of the acoustic backscatter intensity footprints with subsurface contaminant distribution show good correlation, suggesting that areas interpreted by the USGS as probable or possible fill are correlated with areas of documented subsurface contamination. According to the USGS data, fill materials range from about 6 to 7 meters in thickness near the shoreline to less than 1 meter thick at the most distal portions of the fill footprint. Subsurface data collected as part of the RI support this conceptual model of the non-native sediment area.

Depth of contamination is not well correlated with distance from source, reflecting possible separate dumping or discharge events associated with upland site activity. Historical bathymetry may have also played a role in where dumped or discharged material may have accumulated or slumped. Surface sediment contamination does not correlate well with the footprint for accumulated non-native (i.e., fill) material, suggesting additional mechanisms of transport (down-slope sloughing, longshore transport) are likely to have contributed to the redistribution of dumped or discharged material from the site.

1.4.6.6 Sediment Composition

1.4.6.6.1 Anthropogenic Materials

Anthropogenic materials in surface and subsurface sediment were documented during field collection and core processing activities. Characteristics investigated included sediment texture, odor, color, and presence of debris. A detailed description of field observations is presented in Appendices B and C of the MSU RI.

The presence of NAPL was typically indicated by an iridescent sheen on the sediment surface (attributed to residual petroleum/creosote) or staining (sediment darker than surrounding native material). These observations were interpreted as residual petroleum/creosote contaminants bound to the sediment

A slight majority of the 161 surface sediment sampling locations exhibited petroleum sheens. At 7 percent of the stations, heavy sheening or globules of probable wood-treating formulations were observed. Over 40 percent of the shallow subsurface samples exhibited some degree of sheening or staining. Creosote odor was noted in 35 percent of the samples, a number of which also were stained or iridescent; however, the odor may have been due to either residual- or dissolved- phase wood-treating formulations. Either free or residual (noted as staining or sheen) petroleum/creosote product were observed in three deep core samples.

About 25 percent of the locations sampled for surface sediment contained wood debris, ranging from traces to substantial amounts of fragments, chips, or larger pieces.

1.4.6.6.2 Grain Size

To assist in the interpretation of the sediment inorganics data and to evaluate overall trends in the MSU sediment composition, grain size data were collected from the MSU site. A detailed discussion of sediment grain size data is presented in the MSU RI (See Section 2.1.6.6.2;**WESTON 1998**).

Surface sediment composition in the MSU was generally dominated by very fine and fine sand (63 to 2,000 micrometers [μm]; Wentworth Scale), although two relatively distinct areas offshore of the former tank storage facility and west of the Main Slip were finer-grained (particle size less than 63 μm), dominated by coarse silts (31 to 63 μm). Gravely silty sand and sandy silt were also observed at nearshore stations directly east of the eastern Upland Unit property boundary and at one location offshore at a depth of approximately -56 meters MLLW.

Subsurface sediment composition varied with depth below surface, but some general trends were apparent. Over half (59 percent) of the shallow subsurface sampling locations were characterized by an upper layer (0 to 4 feet below mudline) of silt, beneath which sand and silty sand were encountered in all intervals sampled (up to 20 feet below mudline). Deep subsurface samples (32 to 94 feet below mudline) were typically dominated by sands ranging from medium to very fine.

1.4.6.6.3 Total Organic Carbon Content

To assist in the interpretation of the sediment organics data and to allow for TOC-normalization of the data, MSU sediment was analyzed for TOC content. Following is a summary of the detailed discussion of TOC data presented in the MSU RI (See Section 2.1.6.6.3; **WESTON 1998**).

The results of these investigations indicated that the majority of the MSU stations were characterized by a TOC content between 0.5 and 2 percent for surface sediments (0 to 10 cm). Stations with surface sediment TOC content between 2 and 4 percent were located primarily on the relatively flat shelf west of the West Slip and north-northeast of the site. Stations characterized by a surface sediment TOC content greater than 4 percent were predominantly located in the nearshore area north of the upland facility. Higher (greater than 2 percent) sediment organic carbon was generally associated with either woodwaste or sediment with high levels of PAHs.

The average TOC content of sediments collected from 0 to 8 feet below mudline was 2.4 percent, slightly higher than the range of TOC generally observed in the surface (0 to 10 cm) sediment samples. Sediment samples collected at depths greater than 8 feet below mudline were characterized by less than 1 percent TOC.

1.5 ECOLOGICAL SETTING

A detailed description of the ecological setting of the MSU, including habitats and biota, was provided in the Ecological and Human Health Risk Assessment (**WESTON 1998 Appendix K**). The following sections briefly summarize this information.

1.5.1 Intertidal and Subtidal Habitats

Uplands surrounding Elliott Bay have been developed for urban, port, and industrial land uses, resulting in the elimination of nearly all intertidal wetlands and shallow subtidal aquatic habitats (**PTI and Tetra Tech 1988**). Although limited in area (about 2 acres, based on the lowest spring tides), intertidal habitats in the MSU include mud- and sandflats, bulkheads, pilings, and riprap. Presently, the mudflats and sandflats exist as two pocket beaches at the head of the West and Main slips. The remaining intertidal mud or sand occurs only as a thin strip at the toe of the riprapped banks, exposed only at extreme low tides. Subtidal habitats in Elliott Bay primarily consist of sandy silts, and muddy and coarse sands, except at the mouth of the Duwamish River, where sand predominates (**Dexter et al. 1981; PTI and Tetra Tech 1988**). Because the MSU is located in a transition zone between the estuarine environment of the Duwamish River and the marine environment of Elliott Bay, the substrates and waters adjacent to the site likely contain habitat characteristics common to both environments.

1.5.2 Biota

Biota inhabiting the MSU includes marine invertebrates, estuarine and marine fishes (including salmonids), birds, and marine mammals. Some of these species have been classified by the State of Washington and federal government as species of special concern (i.e., requiring protective measures for their perpetuation due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance).

Common marine invertebrate inhabitants of the piling surfaces, riprap, and bulkheaded areas of the MSU include barnacles, tube-dwelling worms, sea anemones, sponges, tunicates, and mussels. Marine invertebrates documented or anticipated to use the offshore subtidal habitat of the MSU include a variety of polychaetes, clams, mussels, crab, and shrimp.

Habitats within the MSU may provide nesting and foraging areas on either a seasonal or year-round basis for numerous estuarine and marine species of fish that are found in Elliott Bay, including Pacific herring, shiner perch, snake prickleback, Pacific tomcod, pile perch, Pacific sand lance, copper rockfish, Pacific staghorn sculpin, and various flatfish species, most notably English sole (**Tetra Tech 1988; Dexter et al. 1981**). The most abundant fish species collected by trawl during the RI included English and slender sole, Pacific hake, and Pacific tomcod.

Salmonids represent the most important anadromous fish present in the vicinity of the MSU. Chinook (currently proposed as a threatened species), pink, and chum salmon are common, while coho and sockeye salmon, steelhead trout, and cutthroat trout are less abundant. Multiple migratory runs of both native and hatchery-reared salmonid stocks occur seasonally in Elliott Bay and the Duwamish River (**Warner and Fritz 1995**). Returning adult salmon congregate at the mouth of the Duwamish River in the vicinity of the MSU prior to upstream migrations, and juvenile salmonids may use the nearshore reaches of the MSU during their physiological transition to marine waters.

Shorelines of and waters overlying the MSU provide habitat for a number of terrestrial and water-dependent birds, including loons, grebes, cormorants, scaups, mergansers, scoters, coots, and gulls. The majority of these birds use the water-column habitat in the vicinity of the MSU during their respective overwintering periods. Two state monitor species, osprey and great blue heron, breed close to and possibly feed on fish within the MSU. However, the great blue heron uses primarily shallow water habitats that can be accessed by wading or perching on structures immediately next to or floating on the water surface. This type of habitat is extremely limited at the site and in some cases exists only under pier structures. Three other state monitor species (the western grebe, horned grebe, and red-necked grebe) and two state candidate species (the common loon and Brandt's cormorant) are also likely to forage or use surface waters associated with the MSU. Two state and federally listed endangered species, the bald eagle and peregrine falcon, have also been observed in the vicinity of the site. The bald eagle may feed on fish in the water column. However, the peregrine falcon feeds primarily on other birds (usually song or shore birds). Occurrence of avian prey species at the site is habitat-limited, thus exposure of the peregrine to site-related contaminants is unlikely.

Marine mammals known to frequently forage in Elliott Bay include harbor seal, California sea lion, and harbor porpoise (**Calambokidas 1991**). Harbor porpoise and harbor seals are year-round residents, while California sea lions use the area for winter feeding (**Pfeifer 1991**). Both harbor seal and California sea lion are state monitor species and have been observed hauled out on floating structures near the site.

1.6 SOURCES OF CONTAMINATION

1.6.1 Historical Sources

The PSR Upland Unit was included on the National Priorities List in May 1994. Inclusion was based on chemicals associated with wood-preservation processes contaminating soil, groundwater, surface water, and sediment at or adjacent to the site. Historical sources of upland soil and groundwater contamination include leaks or spills from tanks and associated piping during chemical storage and transport, and dripping of preservatives from treated wood during handling and storage. Upland soils and groundwater are contaminated with high concentrations of PAHs, PCP, and metals (**RETEC 1997**). LNAPL and DNAPL have also been documented in upland groundwater.

Direct discharge of wood-treating preservatives during processing, storage, and handling of treated logs is most likely the principal mechanism of release to sediment. Historical maps (**RETEC 1994a**) show old outfalls leading from process areas to the bay or nearby waterways that were subsequently filled as part of the historical site expansion. Test pits excavated on-site show no evidence of buried process waste sludges on the site (**RETEC 1994b**), suggesting that direct discharge to the bay may have also been used to dispose of site-generated wastes. Erosion of contaminated soil via surface water runoff and discharge of contaminated groundwater via shoreline seeps or diffuse flow through banks are also considered other historical pathways of chemical release and transport to offshore sediment.

1.6.2 Ongoing Sources

Discharge of groundwater potentially containing dissolved-phase NAPL and NAPL transport represent possible continuing sources of contamination to the MSU. As part of the upland source control activities, a slurry wall and LNAPL recovery trench were constructed along the perimeter of the shoreline with upland extensions (wing walls) in 1996. The wall inhibits transport of shallow LNAPL and dissolved-phase NAPL in shallow groundwater to Elliott Bay. The site has also been capped and paved, thus limiting erosion of soils or infiltration and transport of contaminants to the offshore unit via shallow groundwater (**RETEC 1997**). DNAPL has been documented in wells associated with the former process areas at depths up to 100 feet bgs. Along the central shoreline, DNAPL has been noted in the MW-5 series well, which is located near a buried riprap wall (**RETEC 1997**). The riprap may have sufficient voids to act as a migration pathway from a former outfall terminus leading from retorts 3 through 7 from the former main process area. The slurry wall prevents lateral migration (if any) of shallow DNAPL to the bay; however some DNAPL is present seaward of and deeper than the slurry wall, which may constitute a source to the bay (**RETEC 1997**).

DNAPL was noted in the RW-1 series well that is screened below the depth of the slurry wall (40 feet), with the largest volume noted in well RW-1D (**RETEC 1997**). Additionally, DNAPL occurred in the MW-15 well along the eastern shoreline, east of Tank Area 1 (**RETEC 1997**). The majority of the DNAPL resides in the aquifer under the historical central processing area between 30 to 60 feet bgs. According to **RETEC (1997)**, the deeper DNAPL poses little potential risk to Elliott Bay sediment quality, due to its distance from the bay and a lack of a driving force.

Transport of contaminants dissolved in groundwater from deeper strata may represent a continuing source to sediment from the Upland Unit. The capping and paving of the Upland Unit and wall construction will not prevent the transport of dissolved contaminants from deeper groundwater. An analysis was performed as part of the MSU RI to determine whether existing groundwater quality conditions have the potential to contaminate clean sediment following site remediation. Contaminant fate and transport was modeled assuming a 3-foot thick cap placed over existing contaminated sediments. The model results predict that sediment concentrations for naphthalene and fluorene will exceed the second-lowest Puget Sound Apparent Effects Threshold (2LAET) after 10 years in the intermediate groundwater discharge zone (-25 to -50 feet MLLW). A refinement of this analysis showed that the potential for recontamination is primarily associated with groundwater flowing from the west-central portion of the site where DNAPL has been recovered from wells at all depths sampled. Detailed results of this analysis are discussed in Section 3.3.2.6 of the MSU RI.

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SECTION 2

DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

2.1 INTRODUCTION

This chapter presents information used to develop remedial action objectives (RAOs) for the PSR MSU. RAOs specify the contaminants of concern, the exposure routes and receptors, and preliminary remediation levels. The following information is presented to assist in developing RAOs:

- Nature and extent of contamination
- Human health and ecological risk assessment
- Analysis of applicable or relevant and appropriate requirements (ARARs)

Section 2.2 discusses the nature and extent of contamination for the contaminants of concern at the MSU. The results of the site risk assessment are summarized in Section 2.3. In Section 2.4, ARARs are identified. RAOs and associated numerical sediment cleanup goals are provided in Section 2.5. In Section 2.6 the areas and volumes of media with contaminant concentrations exceeding Sediment Management Standards are provided.

2.2 NATURE AND EXTENT OF CONTAMINATION

The nature and extent of sediment contamination at the MSU is presented in this section. Surface (0 to 10 cm) and subsurface (up to 20 feet below mudline) sediment samples were collected during the RI sampling program to assess the areal and vertical extent of contamination, respectively. Samples were typically analyzed for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins/furans, dibenzofuran, phenolic compounds, and select inorganic constituents.

PAHs were compared to SMS criteria based on group (high and low molecular weight) totals and individual compounds. Total low molecular weight PAHs (LPAHs) represent the sum of the following compounds: acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene. Total high molecular weight PAHs (HPAHs) represent the sum of the following compounds: benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes (sum of the "b", "j," and "k" isomers), chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cp)pyrene, and pyrene. Total PCB values presented are the sum of all detected PCB Aroclor mixtures (e.g., Aroclor 1254 plus Aroclor 1260).

Surface and subsurface sediment chemical data were compared to available sediment effects-based screening values [i.e., SMS and Puget Sound Apparent Effects Thresholds (AETs)] to evaluate the nature and extent of contaminated sediments in the MSU. Because regulatory sediment effects-based screening values are not available for dioxins and furans, the extent of contamination by these compounds was determined by comparison to Elliott Bay background concentrations that were established as part of the RI sampling program. Descriptions of these screening criteria are provided below.

2.2.1 Screening Criteria

2.2.1.1 Chemical Screening Criteria

Washington State SMS (WAC 173-204) provides two sets of chemical concentration effects-based criteria for Puget Sound sediment. Sediment Quality Standards (SQS), established as long-term cleanup goals, correspond to a sediment quality below which will not result in adverse effects on biological resources. Cleanup Screening Levels (CSL) are less stringent standards that correspond to minor adverse effects threshold for biological resources; they are typically used to determine if remediation is required in a specific area. Site-specific cleanup levels are chosen from a range of chemical concentrations whose upper limit is defined by the CSL and whose lower limit is defined by the SQS. Sediment chemical data were compared to both of these criteria. Numerical SQS and CSL are presented in **Table 2-1**.

No sediment criteria for the protection of human health have been promulgated to date. For this site, delineation of those areas of concern for human health is based on SMS chemical criteria. Within those areas defined by the SQS or CSL, standard risk assessment techniques were used to evaluate threats to people eating seafood caught from the site.

For comparisons to SMS, all nonionic/nonpolar organic chemicals were normalized to percent total organic carbon (TOC) content by dividing the dry weight concentration of a given chemical by the decimal fraction of TOC measured in the sample. If station-specific TOC content was outside of the range appropriate for normalization (less than 0.5 or greater then 4.0 percent), nonionic/nonpolar organics chemical results were compared with Puget Sound AETs. These criteria are expressed on a dry weight basis (i.e., non-TOC normalized). AETs represent chemical concentrations above which deleterious biological effects have been demonstrated to always occur; they are the functional equivalent of the SMS chemical criteria. The lowest AET (LAET) was used as the equivalent of the SQS, and the second-lowest AET (2LAET) was used in place of the CSL. AETs are also presented in **Table 2-1**.

2.2.1.2 Elliott Bay Background Screening Levels

Regulatory sediment effects-based screening values are not available for dioxins and furans. Therefore, the extent of contamination by these compounds was evaluated by comparison to Elliott Bay background concentrations that were established as part of the RI sampling program. A background screening level [based on 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) equivalents] was derived by averaging the concentration calculated for each of the four background sampling stations. Only detected values were used in the calculation of the TCDD equivalent. The resulting screening levels are presented in **Table 2-2.**

2.2.2 Surface and Subsurface Sediment Chemical Results

Data reported in the RI were compared with the effects-based screening levels to determine the nature and extent of contamination at the MSU site. The surface and subsurface sediment sample locations are presented in **Figure 2-1** and **2-2**, respectively. **Table 2-3** provides a summary of the surface sediment chemical data and frequency of exceedance of screening criteria on a chemical-specific basis. **Table 2-4** provides a summary of the shallow subsurface (0 to 20 feet below mudline) chemical data and frequency of exceedance of screening criteria on a chemical-specific basis; similar presentations are provided in **Tables 2-5** through **2-9** for data summarized according to each 4-foot composite interval.

Chemicals found to exceed screening levels in surface and subsurface sediment include LPAHs, HPAHs, phenolic compounds, dibenzofuran, dioxins/furans, PCBs, and mercury. The following is a summary of the data interpretation for surface and subsurface contaminant distribution and exceedance areas.

PAHs are the primary chemicals of concern (COCs) in surface and subsurface sediment, based on their widespread distribution at concentrations in excess of effects-based chemical screening criteria. Of more than 100 samples analyzed, concentrations of total LPAHs exceeded SQS or LAET screening criteria in nearly 60 percent of the surface sediment samples and approximately half of the subsurface samples. The CSL or 2LAET screening criteria for LPAHs were also exceeded in nearly one-third of the surface samples and nearly 40 percent of the subsurface samples. Concentrations of individual and total HPAHs were typically lower than LPAHs, relative to their respective screening criteria. Fewer HPAH CSL or 2LAET screening criteria exceedances were observed, compared to LPAH.

Concentrations of PAHs tended to decrease with distance offshore of the Upland Unit and depth below the sediment surface; however, the maximum vertical extent of contamination was not established at four nearshore stations (i.e., EB12, EB13, EB27, and EB113) located offshore of the former tank storage facility and on the relatively flat shelf northwest of the CMS. Core refusal at shallow depths (7 and 12 feet below mudline) occurred at two of these locations (EB12 and EB113), and individual PAHs and/or total LPAHs were detected at concentrations exceeding screening criteria in the deepest intervals sampled at the remaining two locations (16 to 20 feet below mudline).

Other contaminants of concern, including phenolic compounds, dibenzofuran, and dioxins and furans, tended to occur with PAHs and were similarly present at highest concentrations at nearshore locations (predominantly inshore of the Outer Harbor Line). Elevated concentrations of mercury and PCBs (relative to SMS screening criteria) appeared to be more localized, occurring primarily east of the Upland Unit (mercury) and near the Longfellow Creek overflow channel outlet (PCBs). These contaminants do not appear to be related to sources from the Upland Unit.

Because PAHs represent the primary COC in MSU surface sediment, a comparison of these surface sediment data with SMS and AET screening values was used to define the areal extent of contamination of MSU sediment. Stations were designated as exceeding SQS/LAET or CSL/2LAET chemical criteria based on individual PAH results (e.g., a single PAH exceedance of its CSL/2LAET chemical criterion was sufficient for including the station in a defined CSL/2LAET exceedance area). The area associated with each sampling point was derived using Thiessen polygons, as described in the RI. The results of this evaluation indicated that stations exceeding SQS/LAET PAH chemical criteria encompass approximately 100 acres, while stations exceeding CSL/2LAET PAH criteria stations comprise approximately 50 of these acres (see **Figure 2-3**). Approximately 50 acres of sediment within the MSU do not exceed either SQS or CSL PAH chemical criteria. Several additional areas were added to the SQS and CSL cleanup areas, due to the presence of PCBs alone. Polygons associated with EB05, and EB08 at the mouth of the Longfellow Creek overflow were included in the CSL cleanup areas, while polygons associated with EB14, EB24, EB35 and EB106 were included in SQS cleanup areas in the development of the alternatives. All other PCB exceedances are incorporated in PAH cleanup areas.

2.3 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

Human health and ecological risk assessments were conducted as part of the RI to evaluate the potential for current and future impacts of site-related contaminants on receptors that may occur in the vicinity of the MSU. The overall approach focused on risks associated with site-related chemicals where the effects were not addressed by the SMS (i.e., bioaccumulative effects). The estimated risks represent "residual risks," or the risk remaining after a given area of the MSU is remediated. The SMS SQS and CSL chemical exceedance areas for sediments (**Figure 2-3**) were used to establish preliminary cleanup areas that formed the basis of the residual risk estimates. In addition, baseline risks, or those risks that currently exist at the site, were calculated to determine reductions in risk for several cleanup scenarios.

2.3.1 Human Health Risk Assessment

The human health risk assessment evaluated potential cancer and noncancer risks to subsistence fishers, as represented by tribal fishers, who may consume above-average amounts of seafood from the site. Exposures to site-related contaminants through consumption of fish and shellfish collected from the MSU were assessed. A clam bioaccumulation study and a fish tissue investigation were conducted to evaluate the concentrations of contaminants of concern (PAHs, dioxins) that may bioaccumulate in tissues of clams (used as a surrogate species for all shellfish) and demersal fish. Estimates of the amount of fish and shellfish that may be eaten by tribal fishers were derived from a seafood consumption study for two Puget Sound tribes (**Toy et al. 1996**).

Results of the human health risk assessment suggest that cancer risks to subsistence fishers are of primary concern under current conditions. Cancer risks represent an individual's chance of developing cancer due to eating seafood from the MSU, over and above those exposures associated with general activities in a lifetime. Background cancer risk in Elliott Bay is on the order of 1 in 100,000 (2.9E-05). Current excess risk for contracting cancer from ingestion of fish and shellfish collected from the site is slightly greater than 1 in 10,000 (4.6E-04), greater than the maximum risk specified by the National Contingency Plan (NCP) risk management range of less than 1 in 10,000 (1.0E-04) to 1 in 1,000,000 (1.0E-06). The residual risks associated with the remedial alternatives are provided in the evaluation of alternatives in Section 5.3, Evaluation of Sediment Alternatives.

The likelihood of noncancer health threats from ingestion of fish and shellfish collected from the site appears to be minimal. However, noncancer effects from exposure to dioxins were not evaluated due to lack of a promulgated reference dose.

2.3.2 Ecological Risk Assessment

The ecological risk assessment was based on measurements or estimates of effects to benthic invertebrates, bottom fish, and fish eggs. Concentrations of contaminants in the surface sediment were compared with effects-based criteria (i.e., SMS and AET chemical screening values) to evaluate the toxicity of the sediment to benthic organisms. Other site-specific data evaluated in the risk assessment included results of surface sediment bioassay tests and benthic infaunal identification and enumeration, as well as chemical data from fish tissues collected at the site and shellfish exposed to site sediments in a laboratory. Estimates of potential impacts to fish eggs were based on a maternal transfer model.

Results of the ecological risk assessment showed that existing contamination has low to moderate impacts on benthic invertebrate communities residing in the MSU. Remediation of areas exceeding CSL chemical criteria would reduce impacts to benthic communities experiencing moderate impacts. Remediation of areas with PAHs above the SQS would reduce impacts to benthic communities experiencing low impacts.

No risks were calculated for clams because of a lack of effects data in the literature. However, clams are exposed to site-related contaminants at levels exceeding Elliott Bay background levels, indicating the possibility that deleterious impacts could occur to this receptor. Remediation of any of the areas in the MSU would reduce exposures of sessile benthic organisms at the site, such as clams, thus reducing the risk of injury to these organisms.

No risks to fish or fish eggs based on exposure to bioaccumulative contaminants in sediment were identified for the existing conditions in the MSU. However, risks to fish from PAH exposures were not evaluated because tissue concentrations were considered a poor representation of exposure and potential effects, due to the metabolic breakdown of PAHs in vertebrates.

The uncertainties associated with the ecological risk evaluations are presented in Appendix K of the MSU RI.

2.4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

This section presents the ARARs anticipated for sediment remediation of the PSR MSU. The ARARs identified are those anticipated to require consideration during the implementation of the remedial actions proposed in Section 4 of this FS. Final remedy selection and ARAR determinations will be made during the preparation of the Record of Decision (ROD).

Under the Superfund Amendments and Reauthorization Act of 1986 (SARA) and the NCP, the remedial alternatives must be compared against applicable or relevant and appropriate federal and state requirements. "Applicable requirements" refer to those standards, requirements, criteria or limitations that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) site. "Relevant and appropriate requirements" refer to those cleanup standards that, although not applicable, address problems or situations sufficiently similar to those encountered at the site so that their use is suitable.

ARARs may be categorized according to the focus of the requirement: chemical-specific, action-specific, or location-specific. These ARAR categories are defined and anticipated requirements for MSU remediation are identified. To-be-considered items (TBCs) are also examined for guidance in the identification of ARARs. Some of the ARARs may become federal, state, or local permit requirements depending on the remedial action.

2.4.1 Chemical-Specific ARARs

Chemical-specific requirements establish concentration limits or ranges for specific chemicals in various types of environmental media (air, water, soil, sediment, etc.). The following ARARs either establish protective concentration limits or indicate allowable discharge levels.

2.4.1.1 Federal Water Pollution Control Act/Clean Water Act (33 USC 1251-1376; 40 CFR 100-149)

As a requirement of the Clean Water Act (CWA), ambient water quality criteria have been published for the protection of aquatic organisms and human health (40 CFR 131). Although the criteria are non-promulgated concentrations, CERCLA requires the attainment of water quality criteria where relevant and appropriate. Chronic marine criteria are anticipated to be relevant and appropriate to groundwater discharge quality, and acute marine criteria are anticipated to be relevant and appropriate requirements for discharge to marine surface waters during sediment remedial actions (i.e., capping, dredging, and/or disposal actions).

2.4.1.2 Washington State Water Quality Standards for Surface Waters (WAC 173-201A)

Narrative and quantitative standards for the protection of surface water quality have been established in Washington state. Criteria are established for each water body category: Elliott Bay is classified as Class A water. The standards for marine waters are anticipated to be applicable to discharges to surface water during sediment remedial activities (i.e., capping, dredging and/or disposal actions).

2.4.1.3 Washington Sediment Management Standards (WAC 173-204)

Numerical and narrative chemical concentration and biological effects criteria are established for Puget Sound sediment and are anticipated to be applicable to MSU sediment quality. SQS are long-term cleanup goals that correspond to a sediment quality that will not result in adverse effects on biological resources. CSL are less stringent standards that correspond to minor adverse effects on biological resources; they are typically used to determine if remediation is required in a specific area. Chemical CSL are equivalent to minimum cleanup levels (MCUL). Site sediment cleanup standards are established on a site-specific basis from a range of concentrations whose upper limit is defined by the MCUL (to be achieved within 10 years after completion of the cleanup action) and whose lower limit is defined by the SQS (to be achieved at the time of cleanup). Numerical SQS and CSL/MCUL values are presented in **Table 2-1.**

To date, no sediment standards for the protection of human health have been promulgated; however, cleanup based on meeting the SQS is considered to not represent a significant threat to human health (WAC 173-204-100).

2.4.1.4 Model Toxics Control Act (RCW 70.105D, WAC 173-340)

Cleanup goals for surface waters are provided by the Washington State Model Toxics Control Act (MTCA) Subsection 730, and reference Washington State Water Quality Standards (see Section 2.4.1.2). Cleanup levels for sediment under Subsection 760 are currently reserved. Standards for surface sediments have been promulgated under the authority of MTCA and other state statutes (see Section 2.4.1.3, Washington SMS).

2.4.1.5 Controls for New Sources of Air Pollutants (WAC 173-460)

This regulation provides numerical chemical standards for toxic air emissions and control technology requirements for special air pollution sources, such as sites subject to MTCA cleanup regulations. These requirements are anticipated to be applicable only to large-scale dewatering operations required for upland sediment disposal.

2.4.2 Action-Specific ARARs

Action-specific ARARs provide limits or framework for conducting certain activities. They may specify treatment standards or operational requirements.

2.4.2.1 State Water Pollution Control Act (RCW 90.48)/Water Resources Act (RCW 90.54)

Requirements for the use of all known, available and reasonable technologies (AKART) for treating wastewater prior to discharge to state waters are anticipated to be applicable to remedial actions resulting in discharges to surface or groundwater (i.e., dewatering operations). Section 401 requires certification for activities under Corps Section 404 permits. Certification provides an assurance that the actions would not violate any applicable federal or state effluent limits or water quality criteria.

2.4.2.2 Construction in State Waters, Hydraulic Code Rules (RCW 75.20; WAC 220-110)

Hydraulic project approval and associated requirements for construction projects in state waters have been established for the protection of fish and shellfish. Substantive permit requirements are anticipated to be applicable to remedial actions. The Hydraulic Code Rules on dredging (WAC 220-110-240 to 271 and 320) require dredging projects in saltwater areas to incorporate mitigation measures as necessary to achieve no-net-loss of productive capacity of fish and shellfish habitat. The associated technical provisions and timing restrictions are anticipated to be applicable to dredging, capping and/or in-water disposal activities.

2.4.2.3 State Discharge Permit Program/NPDES Program (WAC 173-216, -220)

The Washington state NPDES program provides conditions for authorizing direct discharges to surface waters and specifies point source standards for such discharges. These standards are potentially relevant and appropriate to discharges to surface waters resulting from sediment dewatering operations during remediation. Such on-site actions must achieve substantive permit requirements.

2.4.2.4 Federal Water Quality Criteria (40 CFR 131)

Federal water quality criteria are anticipated to be relevant and appropriate for dredging, capping, and/or disposal activities that could impact surface water quality. Chronic marine criteria are anticipated to be relevant and appropriate to groundwater discharge quality, and acute marine criteria are anticipated to be relevant and appropriate requirements for discharge to marine surface waters during sediment remedial actions (i.e., capping, dredging, and/or disposal actions).

2.4.2.5 Washington State Water Quality Standards for Surface Waters (WAC 173-201-045, -047)

State water quality standards are potentially relevant and appropriate to dredging, capping, and/or disposal activities that could result in discharge to state surface water or sewers, and would be used to develop both short- and long-term performance objectives for the remedial action, with respect to water quality.

2.4.2.6 Clean Water Act Dredge and Fill Requirements Under Sections 401 and 404 (33 USC 401 et seq.; 33 USC 1251-1316; 33 USC 1413; 40 CFR 230, 231; 33 CFR 320-330)

These regulations provide requirements for the discharge of dredged or fill material to waters of the U.S. Guidelines address disposal sites, permit requirements for dredge and fill operations, compliance with water quality laws, project pollution prevention and control, and construction in navigable waters. Authorization of dredge and fill permits is under the jurisdiction of the U.S. Army Corps of Engineers. Applicable or relevant and appropriate substantive permit requirements apply to remedial actions. A Section 404(b)(1) evaluation is required to assess environmental impacts and explain how such impacts would be avoided, minimized, or mitigated.

2.4.2.7 Aquatic Land Management Open Water Disposal Sites (WAC 332-30-166)

Authorization and associated requirements for discharge of clean dredged material into open waters are established by this statute. These requirements are potentially applicable to capping actions.

2.4.2.8 Minimum Functional Standards for Solid Waste Handling (WAC 173-304)

This regulation provides standards for the proper handling and disposal of solid waste materials in Washington state. Disposal facility design and monitoring requirements are specified. Such requirements are anticipated to be only applicable to upland contaminated sediment disposal.

2.4.2.9 Land Disposal Restrictions (40 CFR 268)

Restrictions and requirements for the disposal of solid waste are established by this federal regulation. These requirements are potentially applicable only to upland disposal of contaminated sediments.

2.4.2.10 Dangerous Waste Regulations (WAC 173-303)

This regulation governs the disposal of dangerous waste in Washington State and is anticipated to be applicable to contaminated sediment disposal in an upland site.

2.4.2.11 Noise Control Act of 1974 (RCW 70.107; WAC 173-60)

This statute establishes maximum noise levels that are potentially applicable to construction activities such as dredging, capping, and/or disposal actions.

2.4.3 Location-Specific ARARs

Location-specific requirements restrict either the concentration of hazardous substances or the conduct of activities in vulnerable or protected locations. They may restrict or prohibit certain remedial actions and may apply only to certain portions of the site.

2.4.3.1 Endangered Species Act of 1973 (16 USC 1531 et seq., 50 CFR Part 200, 402)

The bald eagle, marbled murrelet, peregrine falcon, and other avian and marine mammal state monitor species inhabit the site or nearby areas. In addition, Elliott Bay shorelines are used as salmonid migratory routes; the Puget Sound chinook salmon is currently proposed for listing as threatened under the Endangered Species Act. Remediation actions must be performed so as to conserve endangered or threatened species, with approval from the Department of the Interior.

2.4.3.2 Rivers and Harbors Appropriations Act (33 USC 403, 33 CFR 322)

Section 10 of this act establishes permit requirements for activities that may obstruct or alter a navigable waterway; activities that could impede navigation and commerce are prohibited. These substantive permit requirements are anticipated to be applicable to remedial actions, such as dredging and capping, that may affect the navigable portions of the harbor.

2.4.3.3 U.S. Fish and Wildlife Coordination Act (16 USC 661 et seq.)

Elliott Bay shorelines provide potential habitat for bald eagles and other avian species, and MSU surface water is used as a salmonid migratory route. This act prohibits water pollution with any substance deleterious to fish, plant life, or bird life, and requires consultation with the U.S. Fish and Wildlife Service and appropriate state agencies. Criteria are established regarding site selection, navigational impacts, and habitat remediation. The act also requires that fill material on aquatic lands be stabilized to prevent washout. These requirements are anticipated to be relevant and appropriate for remedial activities on the site.

2.4.3.4 Shoreline Management Act (RCW 90.58, WAC 173-14); Coastal Zone Management Act (16 USC 1451 et seq., 15 CFR 923)

Under these statutes, construction or development near shorelines requires locally administered permits. Although the permits need not be attained, remedial actions would comply with requirements that are potentially relevant and appropriate for dredging or capping activities within the shoreline area.

2.4.3.5 Migratory Bird Treaty Act of 1918 (16 USC 703 et seq.)

Migratory birds may occur in habitats in the vicinity of the site. This act requires the protection of ecosystems of special importance to migratory birds against detrimental alteration, pollution, and other environmental degradation. These requirements are anticipated to be relevant and applicable to surface or intertidal areas that may be affected by dredging or sediment disposal.

2.4.3.6 State Aquatic Lands Management Laws and Public Trust Doctrine (RCW 79.90-79.96, WAC 332-20)

The final remedy must be consistent with state laws that promote public access, water dependent uses, uses of renewable resources, and revenue to the state. These requirements are potentially applicable to remedial actions performed within state-owned aquatic lands.

2.4.4 TBCs

TBC items are state and local ordinances, advisories, guidance documents or other requirements that, although not ARARs, may be used in determining the appropriate extent and manner of cleanup. Generally, TBC requirements are used when no federal or state requirements exist for a particular situation.

A list of TBCs for PSR MSU remediation is presented in **Table 2-10**. These items may be used in full or part, depending on the remedial actions selected.

2.4.5 On-Site Permit Exemptions

Under CERCLA 121(e), federal, state, or local permits need not be obtained for remedial actions that are conducted entirely on-site. "On-site" is defined as the "areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action" (40 CFR 300.5). Although a permit is not required, the substantive (nonadministrative) requirements of the permit must be met. Remedial activities performed off-site would require applicable permits.

2.5 RAOs FOR PSR SEDIMENT

RAOs are cleanup goals developed to protect human health and the environment. They are specific to the contaminated media of concern, the affected receptors and exposure pathways, and the cleanup endpoint for a contaminated site. Risk assessment results indicate that the primary receptors of concern are aquatic animals (benthic organisms, shellfish, and fish) and humans exposed to contaminants through the consumption of fish and shellfish collected near the MSU. Therefore, reducing exposure of environmental receptors to contaminated sediments at the site may reduce human health risks. The RAOs for the PSR MSU are:

- Prevent exposure of fish and/or shellfish to contaminated media such that excess cancer risks to subsistence fishers consuming seafood collected from the site are reduced to less than 1 in 10,000.
- Prevent marine organisms from contacting sediments that exceed the SMS chemical criteria to reduce potential unacceptable impacts to the benthic community.

The numeric cleanup goals to attain these objectives are specified by SMS, as discussed in Section 2.2.1, Screening Criteria. The site-specific cleanup levels shall be as close as practicable to the cleanup objective SQS, and may be modified based on consideration of the cost, engineering feasibility and net environmental benefit of different remediation alternatives [WAC 173-204-570(4)]. Factors affecting the selection of cleanup goals will be discussed during the presentation and comparison of the remediation action alternatives for MSU sediments.

2.6 REMEDIATION AREAS AND VOLUMES

To define the areal and vertical boundaries of contaminated sediment at the MSU, the PAH sediment data were compared with SMS chemical criteria. The results of this evaluation indicate that sediments exceeding SQS chemical criteria encompass an area of approximately 94 acres and represent a volume of 970,000 cubic yards. About 30 acres of this area and approximately 200,000 cubic yards of contaminated material are at depths greater than -200 feet MLLW (the practical limit for dredging). Sediments exceeding CSL criteria encompass approximately 47 acres and represent a volume of 470,000 cubic yards, with approximately 7 acres and 45,000 cubic yards at depths greater than -200 feet MLLW. The SQS and CSL exceedance areas are shown in **Figure 2-3**.

As explained in Section 1.4.6.5, *USGS Bottom Surveys*, a study of substrate characteristics conducted by the U.S. Geological Survey indicated that areas of accumulated non-native materials exist in the MSU. As shown by the fill contours in **Figure 2-3**, mounds of contaminated fill may have been placed or accumulated in several areas. The fill area generally extends 700 feet from the Main Slip. Fill materials range from about 6 to 7 meters in thickness near the shoreline to less than 1 meter thick at the most distal portions of the fill footprint with variable thicknesses within the footprint. This pattern of variability in non-native material reflects possible separate dumping or discharge events associated with upland site activity. The fill elevation contours correlate well with the depth of contamination that exceeds both SQS and CSL cleanup criteria based on evaluation of shallow core results. This correlation indicates the fill area is relatively well-defined and contains the majority of contaminants.

During the Phase 2 investigation, WESTON identified another potential fill area outside the USGS study area. This additional area is offshore of the CMS facility (see **Figure 2-3**); contaminated sediment depths range from 4 to 6 meters in thickness.

SECTION 3

IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

3.1 INTRODUCTION

This section identifies and screens various sediment remediation and disposal technologies to determine which should be used to develop remedial alternatives. First general response action categories are identified. Then, the technologies within each response action category are identified, evaluated, and screened. Technologies that pass screening are assembled into alternatives.

3.2 GENERAL RESPONSE ACTIONS AND CLEANUP TECHNOLOGIES

Three general response actions that achieve the project RAOs are:

- Containment
- Removal and disposal and/or treatment
- No Action/Institutions Controls

Technologies that are associated with these response actions include capping, dredging or excavating, and disposal in a nearshore, aquatic or upland facility.

3.2.1 Containment and Associated Technologies

The containment general response action for marine sediment has essentially one applicable technology—capping. Capping consists of placing a layer of clean sediment or other material over the contaminated sediment. A clean fill layer prevents or reduces chemical migration and provides clean habitat to promote establishment of a healthy benthic community. Capping material is usually obtained from other dredging projects in the region.

3.2.2 Removal and Associated Technologies

Removal consists of excavating contaminated material from the environment so that remaining sediments do not constitute a significant threat to aquatic organisms. Removal requires either (1) a disposal location that achieves confinement or isolation of the excavated material from potential receptors, or (2) a treatment process to remove the contaminants or render them nontoxic.

Sediment removal may be completed by excavation or dredging. Shoreline or shallow nearshore sediments are typically removed using land-based or barge-mounted excavators. Sediment removal with an excavator has limited application because of production and depth limitations. Dredging—either mechanical or hydraulic—is the main removal technology for sediment.

Mechanical dredging typically uses a clamshell attached to the end of a crane. The clamshell is lowered through the water via a cable into the sediment. Lifting the clamshell using the operating cable closes the clamshell, enclosing the contaminated sediment. The sediment is then brought to the surface where it is placed onto a barge. Several types of clamshells have been designed to minimize sediment loss during dredging; however, no design currently exists that eliminates water column impacts from resuspended sediments.

Hydraulic dredging consists of removing the sediment through use of a pump-and-dredge head. The suction head of the pipe is lowered into the sediment where the sediment is pulled into the pipe and pumped via pipeline to a disposal facility. A cutterhead can be attached to the end of the dredge head to facilitate the breakup of hard sediments for suctioning.

3.2.2.1 Disposal

The disposal general response action is a component of removal and consists of confining the excavated sediment at a location designed to restrict contaminant mobility to prevent further contact with human or ecological receptors. Disposal may occur with or without prior treatment. Typically, the sediments are placed into a constructed disposal site where they are covered and periodically monitored to prevent contaminant migration and ensure continued isolation from potential receptors.

Disposal options for contaminated sediment consist of confined nearshore disposal (CND), confined aquatic disposal (CAD) or upland disposal.

Nearshore disposal involves constructing a retaining structure (e.g., berm) adjacent to a shoreline and filling it with contaminated sediment. Shorelines, piers, or other structures can form one or more sides of the retaining structure. Retaining structures can be constructed of riprap, sheet pile, sediment, or other types of materials. Retaining structures made of natural sediment or other earthen materials require the sides to be sloped for stability. Riprap has the greatest stability at the steepest slope (1.5H:1V); thus, its use requires less material for berm construction. Riprap's permeability, however, provides limited contaminant confinement. Sand is less permeable, but requires a much shallower slope to achieve stability, so more material is needed for berm construction. After the nearshore area is filled with sediment, its surface is typically equal in height to the surrounding land (i.e., upland is created). CND sites may fill intertidal and subtidal areas to create upland areas that may be used for development. Depending on site-specific conditions, aquatic and terrestrial habitat can be included in the design of a CND facility.

Disposal at a CAD site consists of placing contaminated sediment at a central subtidal location and capping it with clean material. Contaminated sediment is consolidated into a subsurface pile several times the thickness of the original contaminated material over less surface area. A depression may be dredged at the disposal site before filling to increase the capacity of the CAD without increasing its footprint. Some CAD sites on with greater bottom slopes require construction of a subtidal retaining berm to hold the sediment *in situ*. The subtidal berm may be constructed of fine-grained or larger material such as quarry spalls. CAD sites generally require large areas (10 acres or more) in deep water (at least 60 feet deep, so as not to impede navigation) on slopes of 6 percent or less. CAD site design can include habitat enhancement as a design component, depending on site conditions.

Upland disposal consists of either constructing an upland landfill to accept contaminated sediments or disposing of dewatered sediments in an existing facility. Sediments contain a greater volume of water than most landfilled materials and therefore require a liner, cover, leak detection and monitoring to ensure the contaminants remain *in situ*. Upland disposal could include disposal at an existing landfill permitted to accept the types and concentrations of contaminants found in the PSR MSU. Sediments to be dumped at an existing facility would require a local land-based site for consolidation and dewatering prior to hauling.

3.2.2.2 Treatment

Treatment is a potential component of a removal action. It consists of altering the sediment to render the contaminants nontoxic using chemical, physical, or biological processes. Treatment technologies are designed to remove the contaminants; immobilize them to prevent assimilation into living organisms; or change the chemical form to be less toxic or nontoxic.

Treatment technologies that could be used to treat the contaminated sediments consist of thermal treatment processes, solvent extraction processes, and soil washing.

Thermal treatment technology, such as incineration or thermal desorption, subject the sediment to high temperatures (typically up to 900 degrees Fahrenheit for desorption and 3,000 degrees Fahrenheit for incineration). In the incinerator, organic chemicals are vaporized and combusted in the primary combustion chamber. A secondary combustion chamber is used to treat any unburned organic gases. In a thermal desorber, organic chemicals are vaporized, but not necessarily combusted. The organic vapors can be either released into the environment (depending on their concentration) or recondensed to remove them from the vapor stream (depending on the type of desorber).

Solvent extraction processes remove sediment-bound organic chemicals by dissolving them in a solvent. Typical solvents include liquid propane, butane, or triethylamine. The solvent containing the organic chemicals is then processed to separate the organics from the solvent. The result is a concentrated liquid stream containing organic chemicals and a clean solvent stream that is recycled in the process. Solvent extraction processes are adversely affected by the amount of water present in the matrix to be treated; therefore, solvent extraction of sediment would likely require a dewatering step prior to treatment.

Soil washing technology consists of washing contaminated sediment with water-based surfactants to remove the contaminants from the soil. In addition, soil washing technology also separates finer-grained material (which typically contains the majority of contaminants) from coarser-grained materials. Because of size separation, coarser-grained materials, which may constitute most of the soil, may have chemical concentrations below cleanup levels and thus allow other disposal options for a large fraction of the sediment. The wash water containing the contaminants is treated to settle fine particles or remove dissolved contaminants before re-use in the process.

Treatment can be generally performed *in situ* or following removal to another location (*ex situ*). *Ex situ* treatment requires transport to an upland location where sediments can be processed through a treatment facility. There are currently no effective *in situ* treatment processes for sediments covering a large area or subjected to significant flushing.

3.2.3 No Action/Institutional Controls

No Action and institutional controls do not meet RAOs. The No Action alternative will be retained as a baseline alternative with which to compare all other alternatives. The No Action alternative indicates that the MSU remain as is, and there is no risk reduction.

Institutional Contracts are considered administrative requirements such as health advisories, or no-anchorage restrictions. Since institutional controls do not meet RAOs, they will not be evaluated as a stand-alone action. Institutional controls will be included in specific alternatives where needed to preserve the effectiveness of the remedial alternative .

3.3 TECHNOLOGY SCREENING

This section evaluates containment, removal, disposal, and treatment technologies to determine which should be retained for alternative development for the PSR MSU. Technologies are eliminated based on technical difficulties, administrative concerns, or excessive costs. Technologies retained for alternative development need to address sediment quality requirements under the Sediment Management Rule.

3.3.1 Containment Technology Screening

This technology is effective in isolating the contaminants from ecological and human exposure if the cover is adequately thick (3 feet or more). Although contaminant mobility can be reduced with a thinner cap, three feet is necessary to prevent bioturbation by deep-burrowing organisms such as ghost shrimp (**EPA 1994**). Based on sediment grain size and bathymetry, the PSR MSU is not in an erosional area. Therefore, a layer of clean sediment placed over the contaminated sediment is predicted to persist and provide long-term isolation of the contaminants.

Containment technology would protect human health and the environment because a cap prevents exposure to aquatic organisms (and thus, people eating seafood) from contaminants. Placing a layer of clean sediment over contaminated sediment is technically implementable at this site. This technology is retained for further evaluation.

Intrusive actions may impact the effectiveness of the cover. For example, ship anchors could disturb the upper 4 to 5 feet of sediment, affecting cap integrity over time. Institutional controls may be necessary to protect the cap. Long-term monitoring would also be a component of capping to ensure its effectiveness.

As depths increase, more effort would be required to accurately place the material and monitor its thickness. Cap material placed at greater depths may require additional volumes to ensure accurate placement and adequate cap thickness, due to dispersion and limited control over placement. Options to address this issue include accepting irregular cap thickness in deeper portions of the site or allowing placement of a thin-layer cap.

An evaluation was completed to identify potential areas that could be remediated by thin-layer capping. The thin-layer cap would consist of 6 inches of clean sediment over the contaminated sediment. It was assumed that bioturbation would mix the materials such that the surface sediment concentrations would be halved. Areas appropriate for this approach would therefore be those that exceeded SQS by a factor of less than 2. **Table 3-1** shows the locations that have SQS exceedance factors of less than 2.

Approximately 25 percent of the area between the SQS and CSL chemical criteria may be appropriate for thin-layer capping. This area, however, is discontinuous; no more than five of the parcels (EB-144, -136, -127, -137, and -128) border one another. Because of the discontinuous nature of these parcels, thin-layer capping was not further considered for the purpose of developing remedial alternatives in this FS.

3.3.2 Removal Technology Screening

Use of land-based or barge-mounted excavators to remove contaminated sediment is potentially feasible along the shoreline; however, it is technically difficult to implement at depths greater than 40 feet. Although some excavators can reach to depths of 90 feet, only one or two are available in the U.S. In addition, excavators generally do not remove large quantities of material quickly enough for sediment remediation. Excavator buckets contribute to high material losses and resuspension rates. Because of equipment limitations, high resuspension rates, and slow removal rates, the use of excavators for contaminated sediment removal is not retained for further evaluation.

Mechanical dredging is usually performed using a crane-mounted clamshell bucket. Material densities of approximately 60 percent of the *in situ* density can be obtained. Because the clamshell is crane-operated, it has a greater depth capacity than other dredges e.g. conventional hydraulic). Depth capabilities are limited primarily by the quantity of cable on the spool. Although clamshell dredges operating locally are rigged to work in about 60 feet of water, they can achieve depths of 150 to 200 feet with modifications to the amount of cable and reel size mounted on the dredge. Clamshell dredges may have moderate to high resuspension rates due to sediment losses of up to one percent. Depending on the level of sediment contamination, clamshell dredging can be effective.

Because of the depth capabilities and effectiveness in less-contaminated sediment (where resuspension is less of a concern), clamshell dredging is retained for further evaluation.

Hydraulic dredging has low resuspension rates compared to mechanical dredges and high sediment removal rates. However, large quantities of water are typically entrained with the sediment (up to nine times the sediment volume). Hydraulic dredges available in Puget Sound typically have depth operating ranges of 60 to 90 feet. A dredge is usually attached to a mechanical arm that controls lowering and placement of the dredge head. The dredged sediment can be pumped over long distances (up to one mile using an in-line booster pump) to a disposal area. A new dredge design (Eddie Pump™) uses a high-energy vortex to dislodge the sediment that is then pumped via a pipeline to the disposal site. This type of dredge can remove and transfer sediment containing 50 to 60 percent solids, compared to 5 to 10 percent solids with typical hydraulic dredges. The Eddie Pump™ can be equipped to dredge at depths of 150 to 200 feet because it is attached to the end of a cable and controlled by a crane. The Eddie Pump™ dredge is not available locally but can be easily shipped to this region.

Hydraulic dredging has the capability to remove large quantities of sediment efficiently with little resuspension and materials handling. For these reasons, hydraulic dredging is retained for further evaluation.

3.3.3 Disposal Site Technology Screening

Remedies involving removal also require a disposal site. Three types of disposal sites were screened: nearshore, aquatic and upland.

3.3.3.1 Nearshore Confined Disposal

Construction of a confined nearshore disposal (CND) facility requires a relatively large area (depending on the quantity of sediment being disposed) with a relatively flat bottom. Typically, the CND facility is constructed adjacent to an upland area such that the site can be used as an extension of the upland when the sediment site is filled. Regulatory agencies prefer a CND facility that provides an additional benefit beyond disposal (e.g., redevelopment of a water-dependent industry or service, clean habitat, or expanded recreational opportunities). In general, nearshore disposal sites are not technically difficult to construct.

Site characteristics in the PSR vicinity could likely be conducive to creation of intertidal or shallow subtidal benthic habitats, as a component of CND design. Proximity to the mouth of the Duwamish River and the lack of estuarine intertidal habitat may make constructed intertidal habitat desirable.

CND sites could be constructed at several locations within Elliott Bay. Possible locations include areas at the north end of Harbor Island, Pier 91, and Lockheed Shipyard No. 2. These sites, however, may be partially or wholly unavailable due to their use for other purposes. The Lockheed site, if reconfigured, could accommodate MSU sediments.

Because of the availability of potential CND sites near the PSR MSU, the effectiveness and relative ease of construction, and the desirability of high-quality constructed intertidal habitat, nearshore disposal has been retained for further evaluation.

3.3.3.2 Confined Aquatic Disposal

A CAD facility would consist of consolidating the contaminated dredged sediment on a minimally sloping section of Elliott Bay and covering it with clean sand. Two sites have been identified: one near Terminal 90/91 and one in southeastern Elliot Bay. A CAD facility is effective for disposal of contaminated sediment and relatively easy to construct.

CAD has been retained for further evaluation due to its effectiveness in confining sediment and the feasibility of its construction.

3.3.3.3 Upland Disposal

Upland disposal requires large areas of land where the contaminated sediment can be dewatered (if hydraulically dredged) and landfilled. Disposal would require an area of 11 to 22 acres for construction of a disposal cell. Sediment would be hydraulically pumped to this site or loaded from barges into trucks and transported to the site (rail transportation is not available to the potential disposal sites). Typically, if an upland site is used for dewatering and disposal, an area approximately 30 percent larger than that required to dispose of the sediment is needed to allow for settling. The Upland Unit no longer has any undeveloped areas available for such short-term use.

Mechanical dredging does not necessarily need additional settling space since the sediment is likely to be close to *in situ* density when it is removed. However, use of mechanical dredges results in additional handling of the sediment (offloading barges, loading/offloading trucks) between the point of dredging and the point of disposal, which results in additional time, costs, and potential for worker or environmental exposure to contaminants.

An established landfill could be used for disposal instead of constructing a new upland facility. In this instance, the sediment would need to be dewatered (requiring two 2-acre dewatering cells near the point of dredging) and stabilized to ensure no free water was present prior to transport. This may require adding 10 to 50 percent stabilizing agent by volume. The stabilized sediment could then be loaded into trucks and taken to the transfer station near 4th Avenue and Lander Street, where it would be loaded onto transporters for delivery to a landfill that accepts regulated wastes (Subtitle D). Disposal at an established landfill (assumed to be the Roosevelt Landfill in Eastern Washington) is estimated to cost $110 per cubic yard (including the costs for dewatering, handling, shipping, and disposal).

Upland disposal at a newly constructed facility is retained for further evaluation. Disposal of regulated waste at an established landfill is not retained since this option is prohibitively expensive ($59,000,000 for 470,000 cubic yards, to $120,000,000 for 970,000 cubic yards).

3.3.4 Treatment Technology Screening

Many types of treatment processes can treat contaminated sediments. Thermal processes require moisture contents of less than 25 percent (typical *in situ* sediment is about 50 percent water) to keep costs and treatment times to a minimum. Similar restrictions exist for the other types of treatment processes, such as solvent extraction and soil washing. Dewatering cells and/or filter presses would be required for marine sediment pre-treatment. Sediment dewatering is most cost effective when dewatering cells are used. Mechanical methods (i.e., filter presses) are much slower and more costly.

A typical treatment process can treat sediment at rates of 5 to 30 tons (about 7.5 to 45 cubic yards) per hour. Assuming all site sediment could be treated at the maximum capacity of 30 tons per hour, it would require approximately 4 years and 8 years to attain CSLs and SQS levels, respectively, at a continuous operating efficiency of 72 percent.

Dredging can occur at rates an order of magnitude faster than treatment rates. Therefore, either a very large stockpile of dredged sediment would accumulate or the dredging rate would be slowed. Either option has disadvantages. Stockpiling sediment on-site would create a pile of contaminated material approximately 650 feet square by 30 feet high at a minimum. Dredging at a rate comparable to treatment would result in high dredging costs due to dredge operator standby time.

At a minimum, treatment costs alone are estimated at $40 million ($40 per cubic yard), exclusive of dewatering, disposal, dredging, and transportation costs. Additional costs for disposal, dredging and handling could easily double this cost. Stockpiling the sediment to keep costs low would result in a large pile of contaminated material located on the upland portion of the PSR site that would be present for many years and could result in significant ecological and human health exposure concerns and short-term risks. Because of the length of treatment periods, high costs, and potential short-term risks, treatment has not been retained for further evaluation.

3.4 SUMMARY OF IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Based on the identification and screening of technologies, confinement by thick (3-foot) capping to achieve either SQS or CSLs and removal via mechanical or hydraulic dredging to achieve CSLs are retained for use in developing remedial alternatives for sediment cleanup. All forms of disposal, (upland, CND, and CAD) will also be considered.

A summary of technology screening is provided in **Table 3-2**.

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SECTION 4

DEVELOPMENT OF REMEDIAL ALTERNATIVES

4.1 COMMON COMPONENTS

Remedial action alternatives developed for the PSR MSU will include dredging and capping technologies to achieve the cleanup goals. For those alternatives that include removal of contaminated sediment, confined aquatic, nearshore, and upland disposal will be considered. Below is a discussion of many of the elements likely to be used in alternative development.

4.1.1 Dredging Techniques

Two general types of dredges, clamshell or bucket and hydraulic, are applicable to potential sediment removal operations. The dredging-specific methods evaluated in this FS are closed clamshell dredge and three hydraulic dredges, including cutterhead suction dredge, high-energy vortex dredge, and a limited-access hydraulic dredge. These dredges represent the most widely used classes of dredges available. Each dredge has different attributes with respect to excavation capacity, depth limitations, sediment loss or expansion (bulking), and production rates of dredged material. Pertinent aspects of these dredging methods are discussed in following sections and summarized in **Table 4-1.**

Short-term water quality impacts could occur during dredging. Dredge elutriate tests (DRETs) were conducted to predict the water quality impacts of dredging sediment at the MSU. These test results indicate that dredging could result in low-level exceedances of federal marine acute ambient water quality criteria (AWQC) for two LPAHs (phenanthrene and fluoranthene) at the point of dredge (**WESTON 1997**). However, AWQC exceedances at dilution zone distances (typically within several hundred feet from the point of dredging) would be unlikely.

Currently, dredging may be questioned as an appropriate technology for sediment remediation due to water quality impacts from loss of material during dredging. However, dredging of contaminated sediments can be performed to minimize impacts to the water column, biota, and associated habitats by properly operating the dredge, sequencing the dredging process, choosing the appropriate dredging techniques, and monitoring dredging operations. Sediment resuspension can be controlled by such actions as reducing the swing speed or cutterhead rotation or controlling the placement of the dredge on the bottom. Sloughing of contaminated material into dredged areas can be minimized by dredging the upper slopes near the shoreline and the areas under the piers before moving to deeper areas. Sloughing can be further controlled by reducing the amount of undercutting and maintaining existing slopes to the extent possible during dredging. To maintain their stability, shoreline and pier areas will not be undercut.

4.1.1.1 Closed Clamshell Dredge

Closed clamshell dredges consist of a "closed" clamshell bucket attached to the end of a crane **(Figure 4-1)**. The closed clamshell bucket has overlapping side seals and closeable top flaps to minimize material loss. These buckets can range in capacity from 1 to 50 cubic yards. By mounting a differential global positioning system (DGPS) unit on the bucket, bucket position can be monitored.

Some expansion of material occurs with dredging, although material densities of about 60 percent or more of the *in situ* density can be maintained using this method. Silty sands excavated by clamshell dredge can be anticipated to increase in volume by 10 to 20 percent over *in situ* quantities at the time of dredging and disposal, due to sediment bulking factors, dredge type, dredging duration, and consolidation time.

Because the clamshell is crane-operated, it has a greater depth capacity than some other dredges (e.g., conventional hydraulic dredge). Depth capabilities are limited primarily by the quantity of cable on the spool. Clamshell dredges operating locally are equipped to work in water depths of approximately 60 feet; with modifications to the spool size, they can attain 150 to 200 feet. Clamshell dredges can remove up to 3,500 cubic yards per 24-hour day. Material dredged by the clamshell method is typically transported using a barge.

Clamshell dredging typically results in sediment losses of 1 to 2 percent, which can represent a significant recontamination potential depending upon sediment contaminant concentrations; however, proper procedures (rinsing the bucket prior to re-entry) enable total suspended solids (TSS) concentrations to be less than 30 percent above background within 100 feet of the dredging point (**Bergeron 1998**).

An analysis was performed to determine the potential for recontamination during clamshell dredging (see **Appendix A**). It was assumed that dredging results in 2 percent sediment loss and that the associated suspended sediments would deposit in a 1,000-foot-diameter area. Based on these assumptions, dredging 12,400 cubic yards of sediment with 200 mg/kg LPAHs could contaminate an area of 18 acres to SQS (see Appendix A for calculations).

4.1.1.2 Cutterhead Suction Dredge

Cutterhead suction dredges (see **Figure 4-1**) typically have a mechanical arm that controls the lowering and placement of the dredge. A rotating cutterhead loosens the sediment, forming a sediment slurry so that suction can pull the material into a main centrifugal pump. Hydraulic dredges available in Puget Sound typically operate in up to 90 feet of water. DGPS can be used to monitor the location of the dredge intake. The dredged sediment can be pumped over long distances (up to 1 mile) via a pipeline to a disposal area.

This type of dredge generally has low to moderate resuspension rates and high sediment removal rates. Depending on site conditions and dredge operation (e.g., cut depth, swing direction and speed, sediment type), resuspension levels can range from 2 to 300 mg/L above background. Removal rates of 3,000 to 15,000 cubic yards per 24-hour day are attainable. Using this method, sediment is entrained with water (increasing the sediment volume by a factor of nine) necessitating dewatering. Following initial dewatering, the disposed sediment volume generally ranges from 30 to 40 percent greater than *in situ* quantities.

4.1.1.3 High-Energy Vortex Dredge

A new hydraulic dredge design (e.g., Eddie Pump™) (see **Figure 4-1**) uses a high-energy vortex to dislodge sediment that is then pumped via a pipeline to the disposal site. This type of dredge can remove and transfer sediment characterized by 50 to 60 percent solids (similar to *in situ* densities) as compared to other hydraulic dredges that handle only 10 to 20 percent solids. Using an Eddie Pump™, excavated volumes of silty sand generally range from 10 to 20 percent greater than *in situ* quantities. Attainable production rates generally range from 4,000 to 18,000 cubic yards per 24-hour day. Vortex dredges can be designed to work at depth. For example, the Eddie Pump™ can dredge to depths of 200 feet. The cables can be adjusted independently to account for varying slope conditions.

The vortex dredging method has minimal resuspension rates based on observation of the Eddie Pump™ using an underwater camera. Real-time TSS measurements can be monitored utilizing a sensor mounted adjacent to the dredge point. Near-dredge monitoring data from several sites have shown that suspended solids concentrations can be maintained at background levels. As with most hydraulic dredges, the dredged sediment can be pumped over long distances (up to 1 mile) via a pipeline to a disposal area. The Eddie Pump™ dredge is not available locally, but can be shipped to this region via flatbed truck.

4.1.1.4 Limited-Access Hydraulic Dredge

Small hydraulic dredges or hand-held dredges may be necessary to reach areas that are inaccessible to standard dredges in shallow water. Production rates range from 500 to 1,500 cubic yards per 24-hour day. A ring of low-pressure water jets loosens the material that is recovered by a centrifugal pump. The limited-access hydraulic dredges available in Puget Sound typically have operating depths of approximately 40 to 60 feet. Booster pumps can be added to transfer the dredged sediment up to 1 mile via a pipeline to a disposal area.

Depending on site conditions and operation techniques (cut depth, swing direction and speed, sediment type), this type of dredge has resuspension rates ranging from 2 to 300 mg/L above background. As with the cutterhead suction dredge, sediment becomes entrained with water, increasing the sediment volume by a factor of 9. Following dewatering, excavated volumes of silty sand generally range from 30 to 40 percent greater than *in situ* quantities.

4.1.1.5 Dredging Summary

Preliminary results of the dredging evaluation indicate that the majority of the sediments could be removed using either a large hydraulic or clamshell dredge; however, excavation rates for hydraulic dredges far exceed those for a clamshell. Advantages of the hydraulic dredge over closed clamshell include:

- Higher productions rates
- Lower resuspension rates
- Ability to transfer dredged material contained via a pipeline

Advantages of a vortex-type dredge over a conventional hydraulic dredge include:

- Depth capabilities below 90 feet
- Higher solids content of dredged material (less water handling)
- Lower resuspension rates
- Real-time turbidity monitoring near point of dredge

4.1.2 Capping Techniques

Capping as a remedial technology involves placement of clean substrate (typically sand) to some specified depth over the contaminated sediments. Placement is typically achieved by controlled dumping from a split-hulled barge. Where the contaminated sediments are characterized as fine-grained, methods such as hydraulically washing of capping material off a flat-decked barge or distribution via a manifold and submerged diffuser have been used. For example, at the Simpson site in Commencement Bay, sandy material was fed to a large "shaker" box with circular openings cut in the bottom, which was then swung back and forth over the site.

Requirements for capping material depend upon site-specific characteristics, including water depth, bathymetry, currents, and chemical/physical characteristics of the area to be capped. The particle size of the cap material can be selected for either chemical containment or physical containment of the contaminated sediments. In addition, selection of capping material can also reflect habitat restoration goals for specific areas to be remediated. Fine particles are typically more effective in minimizing the migration of chemicals through the cap. Larger-grain particles can be used as armament to prevent erosion from wave action or propeller wash. The particle size and cap thickness can be used together to obtain effective containment of contaminated sediments.

Site-specific physical constraints affecting capping include currents, wave action, propeller wash, and slope. Elliott Bay bottom currents are typically weak, with a mean speed less than 0.3 foot per second (**NOAA 1981; EVS 1996**). This velocity is typically insufficient to resuspend fine sands.

Wave action from wind is anticipated to be minimal because the area is protected from the prevailing wind direction (southwesterly) by the West Seattle ridge. Wave action from vessel traffic occurs in the area of the CMS terminal dock, located immediately west of PSR. The effect of wave action in this area should be minimal because the water depth quickly exceeds 15 feet. Propeller wash in this area may be a greater factor affecting cap erosion, depending on the size of the tugs or the type of propeller.

The angle of repose for sand (20 percent) is estimated to be the approximate maximum slope upon which capping can occur (**Corps nd**); the majority (70 percent) of the site is characterized by slopes less than 20 percent. Slopes within the MSU can therefore be capped, assuming that sand would be used.

To minimize adverse impacts to the environment and increase the potential for rapid recolonization, capping of large areas will be performed in phases. For this FS, a 3-foot layer of silty sand is assumed to chemically and physically confine sediments exceeding CSL or SQS. This cap thickness was selected primarily to prevent bioturbation by deep burrowing organisms (EPA 1994). However, placement of capping material in deeper water (greater than 100 feet) will require use of additional material to ensure a final 3-foot cap, due to greater dispersion of material with depth. The Corps has recommended calculating capping material requirements based on a five-foot thickness in order to achieve a final three-foot layer in deeper water.

4.1.2.1 Capping Material Availability

The source of capping material will likely be from maintenance dredging projects performed for navigational purposes by the Corps. Potential sources of capping material were evaluated based on location, quantity, availability, and grain size. Prior to dredging, the proposed cap material will be characterized to determine the sediment quality and to confirm that the material is compatible for its intended use as a capping medium. Information provided by the Corps indicates that the two largest sources of sediment suitable for capping are the Snohomish and Duwamish rivers.

The capping material availability information provided by the Corps is included in **Appendix B**. Capping material from these two sources is described below and a schedule summarizing the quantity of capping material that may be available from these sources for specific years is shown in **Table 4-2**. Given the demand for capping material throughout Puget Sound, coordination with the Puget Sound Dredge Materials Management Program to develop priorities and schedules for the beneficial reuse of clean dredge material will be needed. Mining/borrowing of marine sediments was not evaluated as part of the FS, but may warrant further investigation as part of the remedial design based on information from the Corps.

Approximately 240,000 cubic yards of material from the lower Snohomish River is dredged every 2 to 3 years. The next dredging cycle is anticipated to occur in the year 2000 or 2001. The material from the lower Snohomish River is generally composed of 70 percent sand and 30 percent silt. Approximately 240,000 cubic yards of material (93 percent sand and 7 percent silt) is also removed from the upper Snohomish River every 2 to 3 years. This material is currently being used for other projects and may not be available until after the year 2002 (**Arden 1998**).

Portions of the Duwamish River are dredged every 2 years; the next dredging cycle will commence in February 1999. Approximately 30,000 to 50,000 cubic yards of material is removed from the settling basin at the head of the navigable channel; approximately 100,000 cubic yards is also dredged from the lower reach of the Duwamish River. Material from the settling basin is greater than 70 percent sand, and the sediment from the lower portion consists primarily of sandy or clayey silts. Use of capping material from the lower Duwamish was not considered for PSR because of its silty characteristics.

4.1.2.2 Cap Placement

Placement of capping material must be performed such that loss of material or mixing with underlying contaminated sediments is minimized. Cap placement can be performed to minimize loss of material beyond the area being capped. This requires consideration of the timing, frequency, and duration of currents, tides, and ship activity. For areas exceeding 15 percent slope, cap placement would start at the base of the slope and move upslope. This approach will improve the slope stability by providing a "moving" berm for the capping material as it is placed up the slope.

In situ sediment characteristics such as water content, liquid limits, and plasticity determine the strength of the contaminated sediment layer to support a cap. Softer sediments (those with higher water content, like the MSU sediments) may require more dispersive methods of placement to prevent disturbance of the contaminated layer. More consolidated sediments (less water content) have greater strength; cap material can be directly dumped on the surface with little disturbance.

Potential methods for placement of capping material include dumping from a split-hull barge and washing off a flat barge (hydraulic placement). These methods are considered feasible for water less than 200 feet deep. Dumping from a barge (or similar techniques that result in a large quantity of material impacting the bottom at one time) can result in resuspension of contaminated bottom material during the initial placement. If the rate of placement is limited to 2 cubic feet per second (about 4 cubic yards per minute or less) contaminated sediment resuspension can be minimized **(Parametrix 1990).** The daily capping rate (assuming a 10-hour day) is approximately 2,000 to 3,000 cubic yards per day. Although material can be spread using a split-hull barge at a rate up to 30 cubic yards per minute, the required travel time, capacity (1,000 to 2,000 cubic yards typical), and availability of these barges could further limit the daily capping rate.

Hydraulic placement uses a large volume of water to force capping material off a barge. The settling velocity of the capping material is decreased because the material sinks as smaller particles instead of as a solid mass. The lower settling velocity reduces the resuspension of contaminated sediment as it lands on the bottom; however, this method generally has higher sediment loss rates and an increase in reconsolidation time for the capping material. Cap placement using this technique is limited to approximately 4 to 5 cubic yards per minute, or 2,000 to 3,000 cubic yards per day.

Use of a submerged discharge may help to reduce the potential impacts to water quality and increase placement accuracy. Techniques for submerged discharge include:

- Submerged diffusers (for hydraulic pipeline placement)
- Tremie tubes (for hydraulic or mechanical placement)
- Clamshell placement

Submerged diffusers are devices attached to the end of hydraulic pipelines to control the rate and pattern of discharge. Diffusers have been successfully used to place and cap contaminated sediments at projects in the Netherlands and Belgium. A capping rate of 2 cubic feet per second (2,000 to 3,000 cubic yards per day) is recommended for diffuser placement to prevent contaminated sediment resuspension (**Parametrix 1990**).

A tremie tube is a telescoping conduit with a typical diameter of 2 to 4 feet. The tube is held vertically with the discharge point near the sea bottom. Capping material is fed to the tube using a loader and a conveyor belt. Although the conduit offers a greater degree of accuracy during placement than uncontrolled dumping, because of its large diameter, there is very little reduction in the momentum of the materials. Thus, displacement of contaminated sediment is a concern of this method. The forces due to currents and waves should be considered prior to the use of tremie tubes due to the weight and rigidity of the structure. Capping rates are approximately 1.6 cubic yards per minute (100 cubic yards per hour, or 1,000 cubic yards per day) because the base of the tremie tube cannot be moved independently of the barge; therefore, less area can be capped at each barge location.

A clamshell bucket can also be used to place capping material. Depending on water depth and currents, capping rates of 3.3 to 6.7 cubic yards per minute (200 to 400 cubic yards per hour) can be achieved using a large (40 to 50 cubic yards) clamshell bucket. Higher capping rates, as compared to the tremie tube, are attainable because the material can be unloaded directly from a barge and a larger area can be covered using a crane. A clamshell is the only dredge type suitable for CAD sites because of its control over cap placement at depths greater than -200 feet MLLW and its ability to protect water quality from sediment resuspension during cap placement. Capping rates of 4,000 cubic yards per day are possible in areas with no space restrictions.

Capping under the piers and adjacent to the shoreline would require more accurate cap placement methods, such as a clamshell bucket or excavator, to obtain the desired placement accuracy. To minimize difficulties associated with inaccessibility, pier removal may be performed prior to capping. This will be evaluated as part of the design.

4.1.2.3 Capping Summary

For this FS, a 3-foot layer of silty sand is assumed to chemically and physically confine sediments exceeding CSL or SQS. With increasing depth, the accuracy of cap placement and the capability to monitor final thickness is reduced. At depths greater than –200 feet MLLW, the Corps' experience has shown the potential for significant loss of capping material and difficulty in obtaining the desired cap thickness; therefore, to estimate cap material requirements, it was assumed that an average cap thickness of 5 feet would be needed to ensure a minimum cap thickness of 3 feet. Additionally, a 15 to 30 percent loss of material during placement may occur depending on the capping method, current velocity, and percentage of fines in the capping material.

Capping material for this project will likely be transported via barges from the Snohomish and Duwamish rivers. The additional cost of using dredge spoils as capping material would be limited to the expense associated with transporting and placing the material at PSR instead of the Puget Sound Dredged Disposal Authority (PSDDA) disposal site.

Because added cost and potential difficulties are associated with subsurface placement using a tremie tube, surface discharge is likely more cost effective. The cost of additional capping material needed to offset material loss from dispersion during dumping, would be less than that of using tremie tube methods.

In areas where fine-grained contaminated sediment may resuspend during cap placement, hydraulic washoff should be used to reduce settling velocity of the capping material. Placement using a split-hull barge may be effective, assuming the material can be discharged at a slow rate. If the capping material cannot be released at the proper rate, split-hull placement should be limited to less-contaminated areas.

The PSR site contains sediment contaminant concentrations several times above the SMS cleanup goals. Therefore, this FS assumes that less dynamic or disruptive capping methods will be used (e.g., hydraulic wash-off). More aggressive capping methods, such as barge split-hull dumping, may result in re-contamination of the cap.

Because the limited availability of capping material requires the MSU to be capped over several years, the cap may become re-contaminated from the surrounding uncapped contaminated sediment during the project's duration. This concern is greatest along the shoreline where contaminant concentrations are the highest. The magnitude of recontamination potential will be minimized by capping the most contaminated sediment first, progressing toward the less contaminated areas in subsequent years.

4.1.3 Contaminated Sediment Transport Methods

Two general vehicles are used to transport dredged material: pipeline and barge. A pipeline can transport dredged material directly from the dredge site to the disposal site. A barge is filled with dredged material and towed to a disposal location, where it can be emptied. Although not commonly used, contaminated sediments can also be placed via clamshell from a barge containing dredged material. The actual sediment transport method selected depends primarily on the dredging method and the distance to the disposal site. The transport method will be determined during the remedial design when final dredge equipment and disposal sites are selected.

4.1.3.1 Pipeline Transport

The pipeline method of transport can use one or a combination of three types of pipelines: floating (supported by pontoon floats), submerged, or onshore.

Floating pipelines are supported on the water surface by pontoon floats with flexible connections to allow movement of the water and dredge machinery. Because a floating pipeline can be moved relatively easily, it can efficiently follow the dredge as it progresses. In active shipping areas, however, a floating pipeline may need to be disassembled to allow vessel passage, thereby increasing the chance of release of residual slurry **(Parametrix 1990)**.

A submerged pipeline, placed below the influence of navigational activities, is typically used in active navigation areas. A submerged pipeline is more difficult to monitor for leaks and repair than floating or onshore pipelines.

An onshore pipeline can be constructed along a shoreline and attached to either a floating or submerged pipeline. It is easily monitored and maintained.

Maximum pipeline length is determined by dredged material characteristics (e.g., grain size, water content) pipe diameter, and dredge horsepower. Pipelines can be used to transport material for more than two miles if booster pumps are used; however, transport costs increase with booster pump usage. In addition, the transport process can be impeded during booster pump failures, requiring a shutdown of the entire transfer system if backup pumps are not installed.

Pipelines, if properly operated and maintained, can transport sediment in a closed system that minimizes the release of contaminants to the water column.

4.1.3.2 Barge Transport

Barging maintains the *in situ* density of the dredged material, which minimizes the need for dewatering and the potential for contaminant loss. Maintaining the *in situ* density is important for disposal at a confined aquatic site because the material will settle faster and spread less on the bottom.

Barges have the ability to transport material long distances without additional equipment (other than a tug) or handling.

Caveats to barge transport include impacts to navigation, the need for large access areas at and between the dredge and disposal sites, and the cost of multiple barges (if necessary to maintain continuous dredge disposal operations).

Methods to prevent release of contaminated material to the water column include: (a) limiting overflow of dredged material by prohibiting overfill of the barge, (b) ensuring that the barge dump doors seal tightly, and (c) restricting full barge standby time to less than 24 hours (to limit potential leaks). Furthermore, a mechanical or hydraulic hull locking device should be engaged prior to barge standby.

4.1.4 Institutional Controls

Institutional controls may be required to maintain the performance of a cap. Institutional controls include administrative or regulatory actions to limit activities that may damage the cap. Site-specific issues that may require institutional controls include anchoring, maintenance dredging and shoreline use.

Institutional controls that prevent ship anchorage in the capped areas may be necessary for all alternatives that include capping. Anchor drag for large vessels may approach depths of 4 to 6 feet, which exceeds cap thickness. Anchoring over the 3-foot cap may result in disturbances that penetrate the full depth of the cap and expose the underlying sediment. Administrative controls would be necessary to prevent anchoring in the capped area, to maintain the structural integrity of the cap and the long-term effectiveness of contaminant containment. The locations of general anchorage areas are displayed in **Figure 1-6**.

Maintenance dredging in the capped areas should be prevented through institutional controls. Maintenance dredging to provide ship access, or accommodate new construction or other development projects should be restricted to ensure confinement of the underlying contaminated sediments.

MSU shoreline restrictions for intrusive recreational activities, such as clam digging, would be implemented for all alternatives. Restrictions may include physical barriers and warning signs to limit digging. These controls would serve to reduce or eliminate the potential for human dermal contact and ingestion of contaminants in sediments, as well as minimize disturbance and resuspension of contaminated sediments along the MSU shore.

4.1.5 Monitoring

Monitoring will be performed during and after remediation to ensure that environmental conditions are protective and cleanup objectives are met. Four types of monitoring should be performed: (1) short-term; (2) post-dredging confirmatory; (3) long-term dredged area; and (4) long-term capped area. Each type of monitoring has specific objectives and content. To provide a basis for FS alternative evaluation, only assumptions about sampling design are described below. *Actual monitoring programs will be developed as part of the Operations, Monitoring, and Maintenance Plan for the site during remedial design.*

4.1.5.1 Short-Term Monitoring

This monitoring would be performed during implementation of the active remedy (dredging and/or capping). The purpose of this monitoring is to ensure that implementation of the remedy does not adversely affect the water column and associated marine biota in the vicinity of the work. Short-term monitoring would consist of water column sampling in three general zones around the work area.

To determine water quality conditions in the area immediately surrounding the work zone, the first set of samples would be collected near the point of dredging and/or capping (i.e., the zone of initial impact). Three stations bounding the zone of initial impact would be sampled.

To ensure water quality is acceptable beyond the work area, the second sampling zone would extend away from the boundary of the initial impact zone (i.e., nearfield). Two stations (one upcurrent and one downcurrent) in the nearfield zone would be sampled.

To provide information about background water quality, the third sampling zone would extend beyond the nearfield, in an area free from any potential dredging effects. One station would be sampled for background information in this zone.

Sampling frequency would depend upon the conditions found. Initially, samples would be collected three times daily for the first week. Sampling frequency would then be decreased to two rounds of samples weekly. Samples would be analyzed in the field for turbidity, dissolved oxygen, and PAHs. At each sample station, samples would be collected at three depths—near the surface, midway between the surface and the bottom, and near the bottom of the water column. Confirmation samples will be analyzed by a lab to assess accuracy of the field results. See **Table 4-3** for a summary of short-term monitoring elements.

4.1.5.2 Post-Remediation Dredging Monitoring

This monitoring would be performed immediately after dredging to ensure that cleanup goals had been met. Sediment samples would be collected from the new sediment surface within the dredged area. The sampling would be completed in phases after an area had been dredged such that additional dredging of the area could be completed (if necessary) without remobilization costs. For instance, sampling could be completed in five phases, each phase consisting of an approximately 20-acre area. See **Table 4-4** for a summary of post-remedial action monitoring to verify the performance of the dredging.

For costing purposes, it is assumed that a sampling frequency of one sample per two acres would be adequate to confirm that cleanup goals had been met. Samples would be analyzed for PAHs and bioassays would be performed.

4.1.5.3 Long-Term Dredge Area Monitoring

Long-term monitoring of the dredged area would be performed to ensure the site was not recontaminated from on-site or off-site sources. Sediment monitoring for PAHs would be performed the first year after remediation and every 5 years thereafter, for 30 years. It was assumed for costing purposes that one composite sample per six acres would be adequate to detect recontamination in dredged areas. Sample locations would be selected based on the areas likely to be recontaminated, such as the intermediate groundwater discharge zone (See **Section 4.1.7.1**), and areas where off-site sources could deposit contamination. See **Table 4-5** for a summary of long-term monitoring elements for dredge areas.

4.1.5.4 Long-Term Capped Area Monitoring

To achieve a 30-year design life for a cap, monitoring, inspection, and maintenance of the cap would be required. Periodic monitoring, consisting of surface and core samples every three acres, would be conducted to evaluate contaminant diffusion through the cap. Subsurface samples would be collected from the bottom one foot of the cap. Sampling would be performed every other year and maintenance would be performed as required. See **Table 4-6** for long-term monitoring elements for capped areas.

In addition, the cap would be inspected for physical damage. A comprehensive inspection would include a visual examination by a diver and/or supplemental technology (e.g., remote camera). At depths greater than -120 feet MLLW, however, diver inspections are infeasible due to physical limitations and low visibility. For inspections in areas dangerous to divers (e.g., under ships), over large expanses of the cap, or at greater depths, remotely operated cameras would be used.

4.1.6 Geotechnical Considerations

This section discusses the results of a preliminary geotechnical evaluation of capping processes and nearshore disposal facility berm construction. This evaluation was conducted to determine if these approaches were technically feasible such that alternatives using these concepts could be implemented. An in-depth slope failure and supporting geotechnical analysis was not performed for the site. If an alternative is selected that includes capping or a nearshore disposal facility, the supporting geotechnical analysis necessary to implement this approach would be performed during remedial design.

4.1.6.1 Capping

The long-term cap integrity is dependent upon the material selected and the environment in which it is constructed. The two most important geotechnical issues when evaluating a site for capping are erosion and stability. As discussed in previous sections, the site is characterized as a relatively low-energy environment with regard to currents, water depth, and operational use (propeller wash/direct haul contact). Therefore, long-term integrity and performance of the cap due to erosion is not a significant concern at this site.

Cap stability is dependent upon the capping materials used, the existing bottom slope, the nature of the existing sediments (internal strength and surface roughness), and the method in which the materials are placed. The stability condition will also change during placement (construction phase), following cap installation (short-term case) and after a period of time when the cap materials have settled/consolidated and have undergone strength gain (long-term case).

Based on preliminary discussions with the Corps, the material most likely available for capping will originate from local dredging projects. Dredged material from these projects is anticipated to be predominately sandy materials. The more coarse-grained the capping material, the greater the internal friction of the sediment following placement of the capping materials and greater grain-to-grain contact of the sediment particles. This higher internal friction or particle contact allows placement of material on steeper slopes. Internal shear strength will increase with compaction/settlement of the placed sediment due to the weight of the material placed above it and the water pressure, resulting in greater grain-to-grain contact and cap stability.

The outer slopes (greater than –120 feet MLLW) on which the cap will be placed range from 0 to 9 percent, with nearshore areas as high as 21 percent.

Placement of capping materials on the steeper slopes encountered at the site may result in some initial downslope integration of cap material. It is difficult to estimate the effects of the slope angle alone, since bottom roughness and the particle size of the capping material play an equally important role in the mechanics of material migration down the slope (spreading process). However, cap material may migrate downslope during the placement until sufficient material is built up on the toe of slope, creating a buttressing effect. The result would be a "tapered" cap with a greater thickness at the toe of slope and a narrowing of the cap material (no less than the required minimum thickness) at the top of slope. The actual thickness of the cap at the toe of slope depends on the slope and material characteristics and the method of placement. It is recommended that the cap material placement begin at the deeper elevations and then proceed up the bottom slope to the shallower elevations, thus creating a buttressing effect for materials placed in advance (and up-slope) of the cap-placement operations.

The cap material selected or specified should possess a smaller fraction of fine-grained materials (silts and clays) such that short-term (after construction) stability may be improved. This assumes that the fine-grained material is mixed within the coarse-grained matrix, allowing cohesive strength to increase for the entire sediment mass as the cap layer consolidates over time.

If a coarse-grained sandy material is used as a cap material, long-term stability of the cap should not be an issue on most of the steep slopes. A more detailed stability analysis using the results of physical property testing on the actual sediment to be used for capping (or establishing a range of acceptable values for contract specifications) will be performed in the remedial design phase of the project if this alternative is selected.

4.1.6.2 CND Facility Containment Berms

Based on the sediment borings installed near the proposed containment berms, the underlying sediment consists of an upper 4- to 6-foot soft sandy silt layer, followed by a loose silty sand layer underlain by medium dense silty and poorly graded sands. Based on a review of the Standard Penetration Resistance values for the underlying medium dense sands, these materials would not be anticipated to experience excessive settlement or bearing capacity failure due to the installation of the berms. Deep-seated bearing-capacity-type failures are therefore not anticipated. The soft silt and loose sand layers, however, possess a much lower internal shear strength that may result in localized shallow bearing capacity concerns. Measures to improve the bearing capacity of these shallow, low-strength materials may include stabilization with riprap to form a high bearing capacity foundation, high-strength geosynthetics to distribute the load and improve foundation-bearing capacity, or staged construction of the berm to allow for strength gain in these underlying soft and loose soils.

The containment berm would be located shoreward of a 12 to 18 percent slope. A more detailed analysis of the bearing capacity and slope stability of this configuration would be performed as part of the remedial design phase. Although it is anticipated that the potential for a deep slope failure surface through the medium dense sands will be low, the potential for a shallow type shear plane through the soft silts is possible.

A preliminary geotechnical evaluation was performed (see **Appendix C**) to determine the potential for failure and to evaluate the feasibility of constructing a nearshore disposal facility. This analysis indicates that a berm with a 2.5 to 1 outward-facing slope will be stable under static conditions (i.e., with a safety factor of 1.5).

4.1.7 Project-Specific Requirements

Specific overall project requirements must be included in each of the alternatives as a result of site-specific conditions. The site-specific conditions that affect the alternatives are listed below.

4.1.7.1 Potential for Recontamination

As part of the upland remedial investigation, it was determined that groundwater meets water quality criteria at the mudline. In addition, as part of the MSU RI, the potential for cap recontamination by dissolved constituents in groundwater was evaluated. Residual and free-phase DNAPL were detected in wells screened at shallow, intermediate, and deep intervals in the west-central portion of the PSR shoreline (MW-1 and MW-5). These areas are located outside of the confining influence of the PSR slurry wall and represent a potential source of contamination. To evaluate the potential impact of groundwater transport on sediment quality, groundwater fate and transport modeling was conducted. The results suggest that the groundwater associated with the intermediate screening interval in the wells enters the bay between -25 and -50 feet MLLW. The west-central portion of the MSU represents the area most likely to be affected by groundwater contaminant transport. The potential for recontamination by several LPAH constituents was predicted in this area within 10 to 20 years, assuming no reduction in DNAPL in shoreline wells. It should be noted that a decrease in DNAPL occurrence has been observed over the last several monitoring periods.

The depth of contamination in sediments influenced by the intermediate groundwater discharge zone in the west-central portion of the MSU is greater than 20 feet, and because of the potential for groundwater transport in this area, it is unclear whether it is feasible to remove all of the contaminated sediment. *Therefore, to achieve cleanup goals and long-term protectiveness, a three-foot cap would be placed in the intermediate groundwater discharge zone for all alternatives. In alternatives where dredging is performed first, capping would follow.*

Recontamination of the cap would depend on the tendency for dissolved contaminants in the groundwater to adsorb to the capping material. Because hydrophobic organic compounds such as PAHs adsorb to sediment organic matter rather than inorganic mineral grains, the tendency for PAHs to adsorb to the sediment cap would increase with organic matter content in the cap. As an example, if the groundwater flowing through the capping material has a concentration of 2 mg/L of napthalene and the cap material has a TOC content of 2 percent, the equilibrium sediment concentration would be approximately 52 mg/kg (dry weight). If the cap material has a TOC content of 0.5 percent, the equilibrium sediment concentration (assuming a partition coefficient (K_{OC}) of 1,288 L/kg) would be approximately 13 mg/kg (dry weight) (4 times less). *Therefore, to minimize PAH adsorption and reduce the potential for cap recontamination, the cap should be composed of low-organic (less than 1 percent) material in this area.*

The intermediate groundwater discharge zone that requires capping in all alternatives to address the potential for recontamination is shown in **Figure 4-2**. This area is approximately 600 feet long by 300 feet wide, lies between -25 and -50 feet MLLW, and begins approximately 200 feet offshore of the CMS dock.

4.1.7.2 Slope Stability

The long-term effectiveness of a cap may be compromised in areas with steep slopes. Slopes greater than 20 percent can be susceptible to sliding, exposing the underlying contaminated sediments. Approximately 28 percent of the SQS exceedance area and 35 percent of the CSL exceedance area have slopes between 18 and 21 percent (see **Figure 1-4**). Shoreline areas have significant depths of contamination and relatively steep slopes. In particular, these areas are located under the PSR piers and run eastward to the northernmost point of land. Areas east of the point also have significant depths of contamination but are less steeply sloped.

The area northwest and east of the PSR piers has contamination exceeding cleanup standards at depths of up to 16 to 20 feet below mudline. The bank along these areas is relatively steep and protected with riprap. Areas west of the piers are less steeply sloped and the contamination exceeding cleanup standards is shallower in depth (4 to 8 feet below mudline).

Slope and USGS sub-bottom profiling data (**Figures 1-3 and 2-3**) suggest the presence of material offshore (consistent with discrete waste dumping events) that may be 16 to 20 feet thick in 6 locations. These areas may be susceptible to static failure, requiring spot removal prior to capping.

Dredging to depths required to achieve cleanup goals along the bank is likely to undermine the shoreline protection and cause slope instability. As a result, portions of the shoreline next to the bank will not be dredged in any of the alternatives; rather, these areas will be capped to achieve the cleanup standards.

Silty sands at depths greater than -10 feet MLLW can typically be dredged to a 3 to 1 slope and remain stable (**McGary 1998**); therefore, feasible dredging zones were determined assuming a 33 percent dredge slope. Based on this analysis, dredging contaminated areas near the shoreline will be considered feasible at a distance ranging from 40 feet to 150 feet outward of the shoreline, depending on location.

No dredging will be considered within a distance of 150 feet from the shoreline in the pier area due to the steep slope. Dredging will not be utilized 40 feet outward from the shoreline in the area southwest of the piers due to stability concerns. The area within 90 feet of the shoreline in front of the former Lockheed site will also not be dredged. Dredging at these distances from the shoreline will avoid impacting the stability of shoreline.

The areas where dredging should be avoided to maintain bank stability are shown in **Figure 4-2**. These areas will be capped to achieve the cleanup goals because contamination exceeding cleanup levels is 4 to 20 feet below mudline, and dredging to these depths may affect the bank integrity. Typical cross-sections for these areas showing the dredging and capping zones are provided in **Figures 4-3, 4-4, and 4-5**. The top few feet of the sediment along the bank is silt and has minimal strength; removal of this material may be required to support the cap. A berm or a bench may need to be constructed at the toe of the slope to retain the capping material as it is placed. These elements of shoreline cap construction will be determined during dredging as part of a pilot cap test.

4.1.7.3 Summary

For all alternatives, the following project elements must be included in order to address site-specific issues affecting cleanups.

- Placement of a cap in the intermediate groundwater discharge zone on the western portion of the MSU regardless of dredging option.
- Use of low-organic content capping material in intermediate groundwater discharge zone.
- No or limited dredging in the shoreline area.
- Institutional controls to protect capped areas from anchor drag or maintenance dredging will vary by alternative.
- Institutional controls to prevent digging in the intertidal areas of the shoreline cap.

4.2 DEVELOPMENT OF SEDIMENT ALTERNATIVES

The following alternatives have been designed to achieve sediment quality that is protective of human health and the environment as defined by the SMS. As reported in the MSU RI report **(WESTON 1998)**, PAHs are the primary contaminants of concern for the MSU. The areas with surface sediment exceeding the SQS or CSL for PAHs are depicted in **Figure 2-3**. The SQS exceedance area represents about 96 acres and 970,000 cubic yards of contaminated material; within that area, 47 acres (470,000 cubic yards) also exceed the CSL. Nearly all sediment volume (90 percent) exceeding the CSL is located at depths of less than -200 feet MLLW. Approximately 85 percent of the sediment volume exceeding the SQS is present at depths less than -200 feet MLLW. Approximately 15 percent and 25 percent of the areas exceeding the CSL and the SQS, respectively, exist at depths greater than -200 feet MLLW.

Dredging all sediment that exceeds the SQS would be technically difficult because removal would approach the practical depth limitations for dredging (200 to 250 feet). In addition, no local disposal sites were identified that could accept 970,000 cubic yards of dredged material. Dredging all sediment to the SQS and disposing of it in a nearshore site (assuming availability and capacity) is roughly estimated to cost over $60 million. Other less-expensive technologies (such as capping) would provide the same level of protectiveness at less cost. For these reasons, dredging all sediment that exceeds the SQS is not considered further. Dredging part of the area that exceeds the SQS or all areas that exceed the CSL criteria will be evaluated since it is likely that a disposal facility can be developed with sufficient capacity to address partial SQS or total CSL exceedance volumes.

4.2.1 Alternative 1—No Action

This alternative consists of no removal or isolation of the contaminants in sediments. No engineering or administrative controls are implemented to prevent human exposure. Ecological impacts and risks associated with no action are detailed in Appendix K of the MSU RI report **(WESTON 1998)**. A no action response would not meet the remedial action objectives for the site, but is provided for comparison purposes to gauge the effectiveness of other alternatives.

4.2.2 Alternative 2—Removal to the CSL

This alternative consists primarily of dredging sediments that exceed the CSL in the MSU as practicable, and disposing of the sediment in an upland, nearshore, or aquatic disposal site. Exceptions to the dredging scenario occur in three areas. Because dredging along the MSU shoreline is likely to undermine shore protection and cause slope instability, shoreline areas would be capped to achieve cleanup levels. The intermediate groundwater discharge zone west of the Main Slip would be capped after dredging is completed to attain cleanup goals. The offshore exceedance areas that are deeper than -200 feet MLLW (the practical limit of dredging) will be capped. The proposed dredging and capping areas for this alternative are provided in **Figure 4-6**.

4.2.2.1 Shoreline Area

The shoreline areas that exceed the CSL (see **Figure 4-6**) would be isolated by placement of a 3-foot-thick cap to achieve cleanup standards. Approximately 15,000 cubic yards of clean sediment would be required to cap the shoreline area, which comprises about 15,000 square yards (3.3 acres).

4.2.2.2 Offshore Area

Dredging of sediment exceeding the CSL would be conducted from the nearshore area (at the boundary of the shoreline cap), to a maximum depth of -200 feet MLLW (the assumed practical limits for dredging). The proposed dredge area is 159,000 square yards (33 acres), as shown in **Figure 4-6**.

Dredging depths were estimated using subsurface sediment data collected during the remedial investigation and are included as **Appendix D**. Generally, the dredge depth decreases with distance from the shoreline. Nearshore areas would require dredging to 16 feet below mudline and outer areas to 4 feet in depth. Based on the exceedance area and dredge depth, this alternative would require dredging 372,000 cubic yards of sediment, including the intermediate groundwater discharge zone. (Note: All dredged material volumes are considered as *in situ* unless otherwise stated.) All sediment would be removed until the CSL were achieved at the exposed sediment surface; therefore, in dredged areas, the remaining sediments would be characterized by PAH concentrations less than or equal to the CSL.

Dredging techniques would be employed as described in **Section 4.1.1**, Dredging Techniques. Because the contaminated sediment in many locations exhibits high concentrations of PAHs, removal should incorporate a dredge method that has a low resuspension rate. Accordingly, it was assumed a high-energy vortex dredge would be used to remove sediments because it can retain *in situ* densities and create little or no turbidity in the surrounding surface water. The dredged sediment would be transported via pipeline directly to a CND site. If a CND site is not feasible, the dredged material would require dewatering for shipment to an upland disposal site or CAD site. Assuming a bulking factor of 15 percent, the disposal facility would need a storage capacity of approximately 428,000 cubic yards. Dredged sediment disposal sites alternatives are described in **Section 4.3**, Development of Disposal Sites Alternatives.

Sediments exceeding the CSL in areas deeper than -200 feet MLLW (about 34,000 square yards, or 7 acres) would be isolated by a 3-foot cap requiring 71,000 cubic yards of clean material.

4.2.2.3 Intermediate Groundwater Discharge Zone

About 50,000 cubic yards of sediment would be dredged to remediate the intermediate groundwater discharge zone. After dredging to remove the contaminated fill materials is completed, a 3-foot-thick cap would be placed on the area to attain cleanup goals. The affected area encompasses 20,000 square yards (approximately 4 acres) and would require 20,000 cubic yards of clean sediment for capping. As explained in **Section 4.1.7.1**, Potential for Recontamination, this cap must be placed due to the potential for recontamination in this area via groundwater transport of dissolved DNAPL.

4.2.2.4 CMS Terminal

CMS operates a barge terminal at Pier 2 (just west of PSR). About 9,000 cubic yards (in a 2-acre area) of contaminated sediments would be dredged from the pier area (**Figure 4-6**). No capping modifications would be needed to accommodate CMS operations; all capping in the operational area of Pier 2 is at a depth of greater than -27 feet MLLW.

4.2.2.5 Monitoring

Short- and long-term monitoring would be performed as described in **Section 4.1.5**, Monitoring. Short-term monitoring would be performed during the implementation of remedial actions to ensure that water column quality is not negatively affected during dredging. Confirmatory monitoring would be performed after dredging to verify that cleanup goals had been met. Long-term monitoring of the MSU would be performed to ensure the effectiveness of the remedy.

4.2.2.6 Institutional Controls

This alternative warrants institutional controls to prevent activities that may disturb capped areas. Disturbances include maintenance dredging, ship anchoring, and intrusive recreational activities.

Intrusive recreational activities (e.g., clam digging) should be restricted along the MSU shoreline to reduce disturbance to capped areas and eliminate the potential for dermal contact and ingestion of contaminants associated with the underlying sediments.

4.2.3 Alternative 3—Capping

Alternative 3 presents two different capping configurations to achieve different potential cleanup levels. As described below, Alternative 3a consists of capping all sediment that exceeds SQS-based cleanup goals. Alternative 3b places capping material over sediment exceeding CSL-based cleanup levels. Exceptions to the capping scenario occur where capping interferes with navigation. In these cases, limited dredging will be performed first, so that the cap elevation matches existing conditions.

4.2.3.1 Alternative 3a—Capping to SQS

This alternative consists of capping all sediment that exceeds SQS-based cleanup goals with 3 feet of clean material. Capping material would be obtained from maintenance dredging projects in the Puget Sound area, characterized by PAH concentrations less than the SQS.

Sediments that exceed SQS criteria in the MSU cover an area of 464,000 square yards (96 acres) to a depth of less than -255 feet MLLW.

The shoreline areas (from shore to a maximum of 150 feet offshore, **Figure 4-7**) that exceed SQS would be isolated with a 3-foot-thick cap to achieve cleanup standards. Approximately 18,000 cubic yards of clean sediment would be required to cap the shoreline area, which comprises about 18,000 square yards (~ 4 acres). Capping the area adjacent to the shoreline and near the public viewing pier would likely be performed using a clamshell dredge to obtain the accuracy needed in placing the cap material. The proposed offshore capping area is 426,000 square yards (88 acres) and would require 740,000 cubic yards of capping material.

The intermediate groundwater discharge zone also would be capped as discussed in Alternative 2 with 20,000 cubic yards of clean sediment.

Because the quantity of cap material needed exceeds annual availability, the volume must be obtained over several years, as material becomes available. Therefore, the cap will be constructed in stages, dependent on the availability of material.

The capping stage sequence is shown in **Figure 4-7**. Areas with the highest contaminant concentrations, including the fill area, would be capped first. The target cap thickness is 3 feet. The cap would progress outward as the remaining capping stages are completed. Generally, contaminant concentrations decrease with distance from the shore. Three stages of capping spanning three years would be required to address the SQS exceedance areas. The area covered and number of capping stages directly depend on the quantity of cap material available each year.

4.2.3.2 Alternative 3b—Capping to CSLs

This alternative is similar to Alternative 3a, but primarily consists of capping all sediment that exceeds CSL-based cleanup goals with 3 feet of clean material. Most sediment that exceeds the CSL is located at depths of less than -200 feet MLLW.

Shoreline areas that exceed CSLs (**Figure 4-8**) would be isolated with a 3-foot-thick cap to achieve cleanup standards. Approximately 15,000 cubic yards of clean sediment would be required to cap the shoreline area, which comprises about 15,000 square yards.

In offshore areas, sediment exceeding the CSL would be capped from the boundary of the shoreline cap to -240 feet MLLW. The proposed offshore capping area is 193,000 square yards (40 acres) and would require 328,000 cubic yards of capping material.

The intermediate groundwater discharge zone would be capped with 20,000 cubic years of clean sediment as discussed in Alternative 2.

Capping of the shoreline, offshore, and intermediate groundwater discharge zone would require staging of the cap as shown in **Figure 4-8**.

During capping of the CSL exceedance area, a portion of the SQS exceedance area (possibly 25 percent) on the fringe of the CSL area would be covered by drifting of the cap material during placement. Cap drift over the SQS exceedance area would vary in thickness.

4.2.3.3 CMS Terminal

CMS requires a 20-foot depth to dock its largest barges at the terminal. The present depths at the terminal are adequate, but provide no allowance for a 3-foot-thick cap. The site detail for CMS is shown in **Figure 4-9**. To accommodate vessel depth requirements under extreme low water conditions (-4 feet MLLW low tide), the area around the CMS terminal with depths less than 30 feet would require dredging prior to cap placement. Dredging before capping would maintain current depths without affecting long-term site use. A triangular area approximately 200 by 300 feet (see **Figures 4-7 and 4-8**) would be dredged to a depth of 3 feet to meet the SQS or CSL criteria and maintain operational depths after capping.

Dredging would remove 3,500 cubic yards of material. Clamshell dredging is recommended because hydraulic dredging is not practical for this volume of sediment. The sediment would be placed in deeper areas (greater that -40 feet MLLW) outward of the CMS terminal. This sediment would then be capped with the rest of the PSR site.

4.2.3.4 Monitoring

Short- and long-term monitoring would be performed as described in **Section 4.1.5**, Monitoring. Short-term monitoring would be performed during the implementation of remedial actions to ensure that the water column quality was not negatively affected during capping. Long-term monitoring of the MSU would be performed to ensure the effectiveness of the remedy.

4.2.3.5 Institutional Controls

This alternative warrants institutional controls to prevent activities that may disturb the cap. Disturbances include maintenance dredging, ship anchoring, and intrusive recreational activities.

4.2.4 Alternative 4—Fill Area Removal and Capping

Alternative 4 presents two different configurations that potentially provide optimal removal of contaminant mass, while reducing cleanup costs. Alternative 4a consists of dredging potential fill material that exceeds SQS cleanup criteria and capping all remaining sediment that exceeds these criteria. Similarly, Alternative 4b removes potential fill material above CSLs and places a cap over the remaining sediment exceeding CSL-based cleanup levels. As with other alternatives, the shoreline out to a maximum of 150 offshore and the intermediate groundwater discharge zone would be capped.

4.2.4.1 Alternative 4a—Fill Area Removal to SQS and Capping

This alternative consists of removing sediment containing contaminants in excess of SQS from the area predicted by the USGS sub-bottom profiling data to be non-native (potential fill) material. The fill area is defined as the area where contaminated material has accumulated to a thickness greater than 3 feet. The fill contours shown in **Figure 4-10** indicate there are several areas where contaminated fill may have been placed. Depth of this material in many areas is approximately 12 to 15 feet. The fill area generally extends outward 700 feet from the main dock (see **Figure 4-10**). The fill elevation contours correlate well with the depth of contamination that exceeds both SQS and CSL cleanup criteria based on evaluation of shallow core results.

A contaminant mass and volume calculation was completed to determine what percentage of the total contaminant mass was contained in the fill area. This evaluation showed that by removing this fill material, 96 percent of the mass of contaminants above SQS was removed, while removing only 39 percent of the total volume of contaminated sediment above SQS standards. A summary of the evaluation is provided in **Table 4-7**.

This alternative removes contaminated fill material such that the sediment remaining in the dredged area after removal meets SQS criteria. SQS would be achieved in the surrounding areas by capping with 3 feet of clean material. Removal and capping areas are shown in **Figure 4-10**.

In this alternative, approximately 328,000 cubic yards of sediment would be dredged within the 24-acre fill area (exclusive of CMS terminal sediments, discussed in **Section 4.2.4.3**). The remaining 70 acres that exceed SQS criteria outside of the fill area would require a total volume of approximately 569,000 cubic yards of clean sediment to construct the cap. The majority of this capping material (531,000 cubic yards) would be placed in the offshore area that extends from near the shoreline to a depth of approximately –240 feet MLLW. The shoreline and intermediate groundwater discharge zone areas above SQS would be capped with 18,000 and 20,000 cubic yards of clean sediment, respectively. Capping would be done in stages as shown in **Figure 4-10**.

The intermediate groundwater discharge zone would be dredged first to remove about 52,000 cubic yards of sediment and then capped. Material would be disposed of on-site in an area to be capped. This volume is included in the offshore dredged volume estimates in **Table 4-8**.

Dredging techniques for this alternative would be similar to the methods previously discussed for Alternative 2. Assuming a bulking factor of 15 percent, the disposal facility would need a storage capacity of approximately 439,000 cubic yards (exclusive of CMS sediment). Dredged sediment transport and disposal site alternatives are described in **Section 4.3**, Development of Disposal Sites Alternatives.

4.2.4.2 Alternative 4b—Fill Area Removal to CSL and Capping

This alternative is similar to Alternative 4a, except the fill area would be dredged until CSL levels were met at the exposed sediment surface. Remaining areas exceeding the CSL outside of the dredged area would be capped with 3 feet of clean material. Capping would not be performed in areas where dredging to the CSL occurred. Dredging and capping areas are shown in **Figure 4-11**.

A contaminant mass and volume evaluation was completed similar to Alternative 4a. This evaluation showed that by removing this fill material, 98 percent of the mass of contaminants above the CSL is removed while removing 70 percent of the total volume of contaminated sediment above the CSL. A summary of the evaluation is provided in **Table 4-8**.

In this alternative, approximately 270,000 cubic yards of sediment would be dredged within the 23-acre fill area (exclusive of CMS sediments, discussed in **Section 4.2.4.3**); 50,000 cubic yards would be dredged from the intermediate groundwater discharge zone. The remaining areas (approximately 24 acres) that exceed the CSL would require about 154,000 cubic yards of clean material to construct a 3-foot cap. Of this total volume, 119,00 cubic yards would be placed offshore, 15,000 cubic yards would be placed along the shoreline, and 20,000 cubic yards would be placed in the intermediate groundwater discharge zone. A portion of the SQS exceedance area would be covered with cap material during capping by sediment drift, as assumed in Alternative 3b.

Placement of the cap could be done in one stage.

Dredging techniques for this alternative would be similar to the methods previously discussed for Alternative 2. The total dredge volume for Alternative 4b is 273,500 cubic yards. Assuming a bulking factor of 15 percent, the disposal facility would need a storage capacity of approximately 315,000 cubic yards (exclusive of dredged CMS sediment).

4.2.4.3 CMS Terminal

About 3,500 cubic yards of sediment would be dredged from the CMS terminal for either alternative 4a or 4b (see **Figures 4-10** and **4-11**). Dredging would maintain the current operational depth of 27 feet after a cap is placed. Dredged sediments would be disposed at a deeper area in the MSU and capped.

4.2.4.4 Monitoring

Short- and long-term monitoring would be performed as described in **Section 4.1.2**, Monitoring. Short-term monitoring would be performed during the implementation of remedial actions to ensure that the water column quality is not negatively affected during dredging and capping. Long-term monitoring of the MSU would be performed to ensure the effectiveness of the remedy.

4.2.4.5 Institutional Controls

This alternative warrants institutional controls to prevent activities that may disturb capped areas along the shoreline or in the intermediate groundwater discharge zone. To ensure the integrity of the cap and the containment of underlying contaminated sediment, this alternative would require the implementation of institutional controls to prevent maintenance dredging, ship anchoring, and clam digging along the capped areas of the MSU shoreline.

4.2.5 Alternative Summary

A summary of the dredging and capping components of each alternative is provided in **Table 4-9**.

4.3 DEVELOPMENT OF DISPOSAL SITE ALTERNATIVES

This section presents a summary of identified potential disposal sites for contaminated sediment from the PSR site. Potential CAD sites, CND facilities, and upland sites are discussed separately below.

4.3.1 CAD Sites

For the purpose of this FS, potential CAD sites were identified based on several criteria, including proximity to PSR, physical dimensions of the site, neighboring activities, and ecological importance of the site.

Specifically, only sites located in Elliott Bay were considered. In addition, sites had to be located at depths between -80 and -200 feet MLLW and have a slope of 6 percent or less. The final consideration was that the site could not be located in high-value aquatic habitat areas or designated mitigation areas.

Figure 4-12 contains a map of Elliott Bay identifying two potential CAD sites. CAD Site 1 is located approximately 0.5 mile northeast of the PSR upland site and lies adjacent the PSDDA disposal site boundary. CAD Site 2 is located in the northwest portion of Elliott Bay near Terminal 91 and the Elliott Bay Marina. This site is approximately 3 miles north-northeast of the PSR upland site. **Table 4-10** summarizes the pertinent aspects (i.e., depth, area, capacity, slope) of each potential CAD site.

In 1976, the Corps Waterways Experimental Station placed approximately 154,000 cubic yards of PCB-contaminated sediment in an experimental dump near the proposed location of CAD Site 1. Information about the location of this experimental placement indicates it is likely to border CAD Site 1 to the north. CAD Site 1 does not appear to be co-located with the experimentally placed sediment.

To minimize water quality impacts at the CAD disposal site, contaminated sediments should have high density for faster settling and less spreading upon placement into the CAD. Therefore, to implement the CAD disposal option, it would be necessary to dredge MSU sediments with a closed clamshell dredge to maintain greater than 60 percent of the *in situ* sediment density. (Note: descriptions and evaluations of alternatives assume the use of a vortex hydraulic dredge).

The native sediments in the area of the CAD sites could be dredged to form a depression in which to place the contaminated sediment. This depression, in conjunction with capping, would confine the contaminated sediment. The clean dredged material could be temporarily placed adjacent to the selected CAD site for capping material. Alternately, a berm could be constructed and the dredged sediment placed within this bermed area. The estimated capacity of each site assumes the site is dredged 15 feet deep with side slopes of 10H:1V.

The volume of clean material required to cap the CAD site was determined using a target thickness of 6 feet (5 feet plus 20 percent material loss) to ensure a 3-foot minimum thickness was achieved over the dredged material. The capping material should be composed primarily of sand to minimize material losses of finer-grained materials.

4.3.2 CND Sites

As with CAD sites, potential nearshore disposal sites were identified based on several selection criteria. To qualify as a potential nearshore disposal site, the area had to be located in Elliott Bay. In addition, the geomorphology of the site had to be stable enough to allow the construction of a retaining berm. Location of nearshore disposal facilities could not conflict with current land or shoreline uses or tribal fishing activities. The site could not be located in high-value aquatic habitat areas or habitat restoration or enhancement areas.

Figure 4-13 contains a map of Elliott Bay identifying potential nearshore disposal sites. **Table 4-11** summarizes the current status of 10 sites evaluated as potential nearshore disposal facilities. Of the 10 sites evaluated, only the nearshore areas associated with PSR and the Lockheed facility are currently available for use as a disposal site for dredged material from PSR.

In general, CND facilities can be constructed at intertidal and/or subtidal elevations. Construction of an intertidal disposal site for PSR sediments is not recommended due to the high concentrations of contaminants present and the difficulty in controlling water quality during construction of intertidal area. In addition, the dredged sediment could take up to a year to consolidate in an intertidal area, before it could be capped. Because of the low cohesive strength of dredged sediment, it is unlikely that a sloping intertidal area could be constructed; therefore, an intertidal area would essentially need to be constructed as a bench. This configuration would not have the capacity necessary to confine all of the MSU dredged sediments. Thus, an intertidal CND is not feasible for PSR sediments.

A CND site close to the PSR MSU was identified in the Lockheed Cleanup Action Plan **(Ecology 1996)**. The Lockheed Cleanup Action Plan proposes that a CND facility be constructed off the north shore of the Lockheed site extending eastward from the PSR site to the West Waterway. The proposed Lockheed CND facility consists predominantly of an intertidal disposal area supported by a constructed subtidal area. This area has a relatively low slope with depths ranging from -5 feet MLLW to -35 feet MLLW; most of the area is below -25 feet MLLW. **Figure 3-1** shows the proposed disposal configuration. Site capacity would be filled by the Lockheed site cleanup in the current site configuration.

If the CND at Lockheed was reconfigured to result in a final elevation equivalent to the current upland the facility could accommodate PSR sediments. Integration of the PSR nearshore disposal site with the Lockheed intertidal disposal site would consist of constructing the Lockheed site such that it abuts the east side of the PSR disposal site. The Lockheed disposal site could utilize the east side of the PSR berm for confinement. This integration is shown in **Figure 3-2.** Depending upon which cleanup alternative for PSR is selected, there could be adequate remaining volume left to dispose of Lockheed sediment in an intertidal manner as portrayed in the Lockheed Cleanup Action Plan. If additional capacity is needed, it could be created by designing the Lockheed portion of the disposal facility with higher final elevations.

(This site is proposed as a multi-user CND site for various sediment removal projects in Elliott Bay).

The contaminated sediment volume at the Lockheed site is estimated to be 1,175,000 cubic yards. Much of this contaminated sediment (860,000 cubic yards) lies within the footprint of the Lockheed proposed disposal area (**Figure 3-2**). Therefore, the disposal capacity needed for sediment from the Lockheed site is approximately 315,000 cubic yards (in-place volume) or 363,000 cubic yards (after dredging). The nearshore disposal capacity (after disposal of PSR sediment) is estimated at 300,000 to 445,000 cubic yards, assuming an intertidal disposal facility for Lockheed sediment was constructed.

Nearshore disposal design may include a berm between the PSR site and one of the Lockheed piers. Several configurations were considered to achieve different capacities based on *in situ* volumes of contaminated sediments. Actual disposal volumes will be affected by bulking that occurs during removal and disposal, calculated at 15 percent using the midpoint of a typical bulking range.

Based on the anticipated storage capacity, two nearshore disposal site configurations (A and B) were selected for further evaluation. These two configurations are discussed below and summarized in **Table 4-12**.

To accept dredged material for Alternative 2 (dredging to CSLs) or Alternative 4a (removal of contaminated fill to SQS), the nearshore disposal configuration depicted in **Figures 4-14 and 4-15** could be constructed. This berm configuration provides a disposal capacity of approximately 480,000 cubic yards. This disposal capacity assumes an *in situ* volume of 430,000 cubic yards and a bulking factor of 15 percent. The approximate length of the berm would be 2,000 feet. The berm would be constructed to an elevation of approximately 15 feet above MLLW, to the same elevation as the upland area. The bottom of the berm would range in depth from approximately -6 feet to -35 feet MLLW. The berm footprint would rest on a relatively flat slope. The width of the berm's footprint would vary with depth to a maximum of 160 feet (approximately) at its deepest point.

As shown in **Figure 4-16**, nearshore disposal configuration B could be constructed to contain the dredged sediment generated as part of Alternative 4b (removal of contaminated fill to CSLs). This berm configuration provides a disposal capacity of approximately 350,000 cubic yards. This disposal capacity assumes an *in situ* volume of 305,000 cubic yards and a bulking factor of 15 percent. This location would require a berm similar to Alternative 2 and 4a, extending east from the PSR Upland Unit. The berm would be approximately 1,900 feet long. The base of the berm would vary in depth from -6 to -35 feet MLLW. The base width would be a maximum of 160 feet at its deepest point.

The berm could consist of riprap with sand infill to act as a barrier to sediment migration through any gaps in the riprap. Dredge water from inside the disposal area could be released through a notch in the top of the berm. Modified elutriate tests (METs) were performed to predict the effluent quality from nearshore dewatering operations. The test results indicate that the discharge of separable dredge water could result in exceedances of federal marine acute ambient water quality criteria (AWQC) for two LPAHs (phenanthrene and napthalene). To protect water quality during the dewatering of dredged sediment, the separable dredge water would be detained using an oil boom and/or activated carbon filter and treated prior to discharge. Water quality sampling would be performed to ensure contaminant levels were acceptable.

To maintain slope stability, dredging of contaminated sediments would not be conducted adjacent to the riprap containment berm. Capping of the sediments in this area would likely be the preferred alternative.

To mitigate water quality impacts during construction, a clean, non-silty aggregate would be used for the berm sand infill.

It is assumed that vortex hydraulic dredging would be used to minimize solids resuspension, because of the high concentrations of contaminants in the sediment. The hydraulically dredged solids would likely be pumped via floating pipeline (assumed for costing purposes) to the south side of the disposal site so that suspended solids would have adequate settling time before release into Elliott Bay. Areas of greatest contamination would be dredged first and placed at the back of the disposal site, allowing the suspended solids more time to settle. Areas of least contamination would be dredged last.

The area within the berm would be filled with contaminated sediment to an elevation of approximately 10 feet MLLW to ensure that the sediments remain saturated. The remaining three to five feet would be filled with clean material to serve as a cap.

This site was also evaluated for an intertidal CND facility. Site design would be similar to an upland nearshore disposal site except for a shoreline elevation (including final clean cap material) of approximately 6 feet MLLW, instead of 15 feet MLLW and a base elevation of approximately 0 feet MLLW.

An intertidal CND site was not selected for further consideration in this FS for two reasons. First, it would be difficult to construct a facility using dredged sediment of the type and contaminant level that is characteristic of PSR sediment. The sediment consists of a high percentage of fines that will render it self-leveling and slow to settle. It is unlikely that enough strength would develop in the sediment to ensure the proper slope could be maintained during construction without significant consolidation periods. In addition, because tides frequently exceed 3 feet MLLW, the sediment may never dewater sufficiently during construction to support a cap. An intertidal disposal site will also likely result in water quality impacts due to release of separable dredge water inundating the disposal site during the higher tides.

Secondly, an intertidal disposal site may lack capacity to accommodate both the PSR and the Lockheed sediment.

To incorporate habitat into the PSR nearshore disposal facility design, the outer perimeter of the berm could be covered with fine substrate conducive to benthic habitat. This would create a 5-acre intertidal area extending outward from the top of the berm to a distance of approximately 150 feet at a 3:1 slope. It would range in elevation from -35 feet MLLW to 15 feet MLLW. A cross-section of the berm is shown in **Figure 4-15**.

4.3.3 Upland Disposal Sites

Twelve undeveloped areas identified by the Corps were evaluated as potential upland disposal sites (**Figure 4-17**). The 12 sites are described in **Table 4-13**. The current land use and site characteristics were determined for each location by reviewing topographic maps and King County assessment maps, and performing field surveys. Ten sites were eliminated from further consideration based on current land use (i.e., golf course, park, or watershed buffer zone).

Following the initial review, Sites 1 and 4 remained as potential upland disposal sites. Site 1 is owned by the City of Kent and consists of approximately 152 acres zoned for industrial use. This undeveloped property is located south of South 212th Street and east of the Green River. The eastern portion of the site (approximately 30 acres) is located within the 100-year floodplain. The site is flat and the depth to groundwater is approximately 10 to 15 feet bgs. This site is located approximately 18 miles (via Interstate 5) from PSR.

Site 4 is owned by the City of Renton and consists of approximately 73 acres zoned for industrial use. This undeveloped property is located south of Southwest 27th Street, and east and west of Long Acres Parkway, within 0.5 mile (east) of the Green River. The site is flat and the depth to groundwater is approximately 10 to 15 feet bgs. Site 4 is located approximately 16 miles from PSR via Interstate 5 and SR-405.

As with the nearshore disposal alternative, it is assumed that vortex hydraulic dredging would be used to remove the contaminated sediments from the MSU. The hydraulically dredged sediments would be transported to a dewatering system consisting of two 2-to 3-acre dewatering cells (site is currently undetermined, but would need to be in close proximity). After dewatering, the sediments would be transported to the upland disposal site. Construction of a lined landfill would be needed to contain the dredged sediments. Based on the maximum concentration of contaminants reported in the RI, it is assumed that the sediments would not be considered a state dangerous waste and could be disposed of as a solid waste.

WAC 173-304-130 requires at least 10 feet between the bottom of a landfill and the seasonal high water elevation; therefore, the landfill would need to be constructed on the ground surface. Assuming the dredged material was placed with a 10-foot average fill thickness, a minimum of 35 acres would be needed to contain 480,000 cubic yards (Alternatives 2 and 4a). If Alternative

4b was selected, a minimum of 25 acres would be needed to contain the 315,000 cubic yards of dredged material. Due to shallow groundwater at Sites 1 and 4, sufficient capping material may not be available from landfill construction. Capping soil would need to be imported or obtained from other portions of these sites not used for the landfill.

4.3.4 Summary

Based on the above information, two CAD sites, one nearshore site, and two upland sites will be evaluated further for disposal of contaminated sediment.

SECTION 5

DETAILED EVALUATION OF ALTERNATIVES

5.1 INTRODUCTION

This section presents the criteria used to evaluate individual remedial alternatives being considered for the PSR MSU and provides the results of the evaluation.

5.2 ANALYSIS CRITERIA

The detailed evaluation is based on seven of the nine criteria required by the CERCLA process. Community and state acceptance are evaluated when the preferred remedial action is proposed.

5.2.1 Overall Protection of Human Health and the Environment

Evaluation of the alternatives against this criterion establishes whether the remedial action achieves and maintains adequate protection of human health and the environment. An assessment of how site risks from the various pathways are eliminated, reduced, or controlled through treatment, engineering, or institutional controls is made. This evaluation draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

5.2.2 Compliance with ARARs

This criterion establishes how each alternative complies with federal and state requirements that are considered ARARs to cleanup of the site. Chemical-, location- and action-specific ARARs will be addressed. Other advisories, criteria, or guidance (TBCs) may be used as additional restrictions, as appropriate. The evaluation of each alternative indicates whether requirements are applicable or relevant and appropriate to an alternative and describes how the remedial action complies with these requirements.

The residual human health risks associated with site-related contaminants after remediation were calculated for each alternative. These calculations are provided in **Appendix H**.

5.2.3 Reduction of Toxicity, Mobility or Volume

The degree to which alternatives reduce the toxicity, mobility, or volume of contamination, and overall risk is evaluated using this criterion. Factors that are considered for each alternative include:

1. The degree of expected reductions in toxicity, mobility, and volume of contamination.
2. The method by which contaminant mobility is reduced (e.g., contaminants converted to a non-mobile form or confined such that the contaminants are not released into the environment).
3. The method by which a reduction in toxicity is achieved (e.g., chemically or physically converted to a benign form or removed from the contaminated media so that it is no longer toxic to organisms).
4. The method by which volume is reduced (e.g., treated to decrease the amount of contaminated media).
5. Overall risks for human health and the environment following implementation of the alternative.

5.2.4 Short-Term Effectiveness

Short-term effectiveness focuses on issues specific to implementation of the cleanup action. The following factors are evaluated: (1) human health and environmental risks from exposure to contaminated sediments, (2) risks to worker safety during implementation, (3) habitat loss, (4) water quality impacts, and (5) the duration of implementation.

5.2.5 Long-Term Effectiveness and Permanence

This evaluation is based on the remaining risk at the site after the remedial action objectives have been met. Long-term reliability of the remedial action and the associated need for monitoring and maintenance are assessed. The extent, adequacy, and reliability of controls required to manage the residual risk (e.g., containment systems or institutional controls) are also addressed.

5.2.6 Implementability

Implementability is evaluated based on (1) technical constructability; (2) reliability of the technology; (3) monitoring effectiveness; (4) availability of materials and services (including disposal sites); (5) coordination with agencies, tribes, and other groups; and (6) the duration of the implementation period.

5.2.7 Cost

This evaluation estimates the cost of the remedial action alternative. Items evaluated with respect to cost include capital costs, indirect costs, and operations and maintenance (O&M) costs. Capital costs include expenditures for equipment, labor, materials, land, rentals, and utilities needed to remediate the site. Indirect costs include license or permitting costs, contingencies, and engineering expenses. Maintenance costs are expenses incurred to ensure effective long-term implementation of the alternative. Maintenance costs may include annual monitoring costs, labor, repairs to facilities, resource or utility costs, equipment, and administrative costs.

Engineering expenses include the costs to prepare the design specifications directing site remediation. These costs include engineering labor, drafting, computer time, cost estimating, scheduling, reproduction, communications, and other miscellaneous items needed to complete the design.

Administrative expenses include costs for permitting, public relations, invoking institutional controls, establishing the responsible organization for directing post-remediation monitoring, performance of periodic post-remediation performance reviews, and other items not directly related to engineering.

The present worth of the alternatives uses a discount factor of five percent. The present worth is defined as the value of an alternative in current (1998) dollars where expenditures are expected to occur for a period of years. All costs were computed with 1998 as the base year.

For costing purposes, it was assumed that a vortex dredge (i.e., Eddie Pump™) would be used for most sediment removal at the PSR MSU. Although a vortex dredge was assumed to be the primary method of sediment excavation, a clamshell dredge was evaluated for CAD site options because of significant costs associated with control of sediment resuspension from hydraulic dredging. Final dredge equipment selections will be made during remedial design.

The costs presented in the following alternatives are provided for comparative purposes only. These costs were developed using numerous assumptions with regard to cleanup depth, cleanup goals, areal extent, capping requirements, sediment disposal sites, and other factors. These details will be defined more accurately in the remedial design. The preliminary cost estimates provided in this report should be used only as an indication of the relative costs among the alternatives. The estimates are within +/- 30 percent of actual costs.

5.3 EVALUATION OF SEDIMENT ALTERNATIVES

5.3.1 Alternative 1—No Action

5.3.1.1 Overall Protection of Human Health and the Environment

The No Action alternative is provided for evaluating existing conditions at the site and to gauge the effectiveness of other alternatives. The PSR MSU is contaminated with PAHs at concentrations that exceed SMS criteria. The human health risks associated with site-related contaminants are estimated to be roughly 1 in 10,000 (specifically, 4.6E-04). Ecological and human health risks associated with site contamination are presented in the RI report (Appendix K; **WESTON 1998**). Although slight reductions of contaminant concentrations due to natural recovery processes are possible, the long-term protectiveness of this alternative is negligible because substantial reductions in ecological or human health would not be achieved. In addition, sediment may also be transported off-site and contaminate other areas.

5.3.1.2 Compliance with ARARs

Under this alternative, contaminated sediment would be left in place with no remediation. Leaving sediment in place with contamination above acceptable levels as established by SMS (WAC 173-204) would not meet the requirements of this ARAR. In addition, the current site risks (4.6E-04) exceed the NCP risk management range of 1 in 10,000 to 1 in a million (1.0E-04 to 1.0E-06).

5.3.1.3 Reduction in Toxicity, Mobility, or Volume of Contaminants

In the No Action alternative, no steps would be taken to reduce the volume, toxicity, or mobility of the contaminants in the sediment. It is possible that organics may degrade, slightly reducing the toxicity and volume in the long-term. The degree and time required for any such reductions is unknown; however, given the anaerobic conditions of much of the sediment, microbial degradation is likely to be a very slow process.

5.3.1.4 Short-Term Effectiveness

The No Action alternative has no short-term risks associated with the remedial action to the community, environment, water quality, habitat, or workers because no remedial action is performed. This alternative has no implementation period and the time before remedial action objectives are met is indefinite.

5.3.1.5 Long-Term Effectiveness and Permanence

The degree of long-term effectiveness resulting from implementation of the No Action alternative would be negligible. Human health risks associated with the ingestion of seafood harvested in or around the site would not be reduced and the benthic communities would continue to be exposed to sediment contaminants. In addition, sediment may be transported off-site and redistributed, potentially exposing more aquatic organisms. No institutional controls would be implemented to address long-term effectiveness or performance.

The present condition of the marine habitat in the MSU and the associated risks may be slightly improved over time due to natural recovery processes such as biodegradation, bioturbation, and burial. Although PAHs are only moderately persistent, sediment concentrations are high and the possibility of recovery due to degradation is low. The chemicals present in the sediment act as a disturbance to benthic communities and prevent development of a mature community characterized by deep burrowing organisms. The mixing of cleaner sediments with contaminated sediments due to biological activity is limited, unreliable and contributes little to natural recovery. Because the MSU is characterized by low sediment deposition rates, recovery by burial is also unlikely. The No Action alternative is not considered an effective or permanent solution.

5.3.1.6 Implementability

The No Action alternative requires no implementation.

5.3.1.7 Cost

No cost is associated with the No Action alternative.

5.3.2 Alternative 2—Removal to CSLs

5.3.2.1 Overall Protection of Human Health and the Environment

Alternative 2 would provide long-term protection of human health and the environment by dredging and/or capping sediments with contaminant concentrations in excess of CSL chemical criteria. The majority of the offshore contaminated sediment exceeding the CSL would be removed, exposing the cleaner underlying sediment, and the shoreline and deep offshore contaminated sediment would be capped by clean material (i.e., equivalent to background concentrations). In addition, the intermediate groundwater discharge zone west of the Main Slip would be capped after dredging.

This alternative would reduce long-term risks to human health from seafood ingestion by reducing the exposure of edible fish and shellfish to contaminant concentrations greater than the CSL. Residual human health risks associated with site-related contaminants left in place would be approximately 1 in 10,000 (1.3E-04). Therefore, Alternative 2 would reduce site risk by 72 percent. The resulting noncancerous hazard index associated with the site would be <1.0.

This alternative protects the environment by removing the most contaminated nearshore and offshore sediments, isolating shoreline and deep offshore contaminated sediments from biota and the water column, and providing cleaner substrate for benthic habitat. Although water quality impacts during remediation may pose short-term adverse effects to threatened or endangered species, this alternative would provide long-term protection of habitat for these species.

5.3.2.2 Compliance with ARARs

Alternative 2 would comply with SMS by dredging sediments with contaminant concentrations exceeding CSLs. The residual risks associated with removal are about 1 in 10,000 (1.3E-04) and would meet the NCP risk management range of 1 in 10,000 to 1 in 1,000,000, albeit at the lower end of the range.

The alternative would be performed to satisfy federal and state ARARs for ambient water quality during remedial actions. Because the action involves dredging and filling in waters of the U.S., substantive dredge requirements of the Clean Water Act under Sections 401 and 404 would be met. In addition, a Section 404(b)(1) and Clean Water Act evaluation would be performed to assess environmental impacts and impact avoidance, minimization, or mitigation. As required by the Endangered Species Act of 1973, the remediation would restore habitat available to endangered or threatened species (MSU provides migratory and transitional habitat for some salmonid species proposed for listing).

Implementation of the removal alternative would be designed such that there was no net loss of fish and shellfish production over the long-term or permanent obstruction or alteration of navigable waterway. In doing so, the remediation action would comply with applicable substantive requirements for construction in waters (i.e., Hydraulic Code Rules and Shoreline/Coastal Zone Management Acts) and would meet substantive requirements of the Rivers and Harbors Appropriations Act.

The remedial action could be selected, designed, and coordinated with appropriate agencies to ensure that current or future uses of the waterway are maintained, chemical-, location-, and action-specific ARARs are met, and goals of adjacent cleanup actions are accommodated (i.e., the remedy is consistent with the draft cleanup action plan proposed for the Lockheed nearshore area).

5.3.2.3 Reduction in Toxicity, Mobility, or Volume of Contaminants

Contaminant mobility in the offshore areas would be reduced by removing the contaminated sediment from the MSU and placing it in a confined disposal facility. Contaminant mobility in the nearshore, deep offshore, and intermediate groundwater discharge zone would be reduced by a cap of clean sediment. This reduction in mobility would be achieved by physical isolation rather than treatment. Monitoring and maintenance of the on-site cap and the disposal site for dredged sediments would be required to ensure that physical isolation of the contaminants is maintained. Toxicity and volume would not be reduced under the alternative, but confinement of the contaminated sediment would prevent human and biotic exposure.

5.3.2.4 Short-Term Effectiveness

Alternative 2 would present potential short-term risk to human health and biota from potential exposure to contaminated sediments due to resuspension during dredging, handling, and transport and disposal. Because of work hazards associated with dredging machinery, Alternative 2 may also constitute a risk to worker safety.

Dredging and capping would cause a short-term loss of aquatic habitat (about 228,000 square yards or 47 acres) and biota; however, habitat and associated biological communities would improve after cleaner sediments are exposed or provided by capping.

The severity of short-term water quality impacts was evaluated based on the volume of material dredged and the dredge method used. Alternative 2 could pose extensive impacts to water quality because of the large volume of sediments dredged (about 372,000 cubic yards); however, if a hydraulic vortex dredge were used (presumably in conjunction with upland or nearshore disposal), contaminated sediment resuspension in the water column would be minimized. If disposal at a CAD site necessitates clamshell dredging, water quality impacts would be more severe.

Cap placement would cause short-term water quality impacts from suspended sediments as the cap material travels through the water column. Additional water quality impacts could occur from the resuspension of contaminated sediments by the impact of cap material. The severity of impacts was evaluated based on the dredge volume, the cap area, and the operable depths (i.e., work at greater depths is more difficult, would affect more water column during capping, and disturb a larger sediment area during capping). Because the nearshore area and intermediate groundwater discharge zone comprise a small area (about 7 acres) and the cap would be placed at shallow depths (less than –50 ft MLLW), sediment resuspension during nearshore capping would be low. Offshore capping areas from –200 ft MLLW to –240 ft MLLW would have a greater potential for water quality impacts related to depth, although the acreage is small (about 7 acres).

The implementation period for this alternative (about 2.7 years, depending on cap material availability) is very short primarily because of the small volume of cap material needed. The implementation schedule is provided in **Appendix E**.

5.3.2.5 Long-Term Effectiveness and Permanence

Alternative 2 would achieve a high degree of long-term remedial effectiveness and permanence because most sediment that exceeds the CSL would be removed from the MSU. The potential for reintroduction of contaminants into the MSU from post-remedial sources (specifically, capped areas and the intermediate groundwater discharge zone) is low; capping is recognized as an effective chemical containment technology and the intermediate groundwater discharge zone would be dredged before capping.

Capped sediments present a low potential for confinement failure. The permanence of sediment isolation in capped areas could be affected by seismic and physical disturbances. In general, of the MSU is in a geotechnically stable area; however, this area may be subject to seismic disturbances. Water circulation and wave energy within deeper areas of the MSU are generally non-erosive.

The reliability of the remediation approach offered by Alternative 2 would depend on monitoring and maintenance of the capped areas. All capped areas of Alternative 2 could be effectively monitored and maintained long-term using current methods and technologies. Difficulties in monitoring and maintaining a sediment cap increase with increasing area, slope, and depth.

Alternative 2 has a relatively small area of capped sediment equally divided between shallow shoreline locations and flat offshore locations.

Alternative 2 would require institutional controls to protect capped areas from disturbances by ships anchoring in the vicinity of the deep offshore and shoreline caps and clamming along the shoreline. Maritime controls could be difficult to implement; public access controls that are currently in place may be difficult to enforce. These controls would be necessary and critical to the long-term effectiveness of capped areas.

5.3.2.6 Implementability

Alternative 2—Dredging is technically implementable. Dredging technologies are available that operate effectively in shallow areas and at greater depths, with relatively good accuracy and precision of the device. Capping small shoreline areas of the MSU would be difficult, in terms of cap placement accuracy, around piers and on sloped shoreline areas. Technologies to control cap placement, such as a clamshell dredge or a tremie tube are commonly available. Capping on nearshore slopes can be implemented by modifications to materials (e.g., using coarser materials) or design (e.g., incorporating retaining berms). The cap placement and control of resuspended contaminated sediments in the small offshore areas of the MSU would be difficult to implement for this (and all other) alternatives because of the depth of the cap.

Alternative 2 offers a reliable technology for sediment remediation in terms of the volume of sediments either removed or contained. Alternative 2 effectively removes a large volume of contaminated sediments and contains smaller areas of contaminated shoreline and deep offshore sediments.

Monitoring effectiveness of the technology was based on the cap area, assuming dredged areas would require only limited monitoring. Alternative 2 could be effectively monitored because the cap area is relatively small; however, the offshore cap area is in deep water (>200 MLLW), which will limit the monitoring tools available.

Alternative 2 was evaluated for the availability of capping materials and disposal sites. Capping material for this alternative is readily available; however, a disposal site with adequate capacity would be difficult to site and existing disposal facilities are either prohibitively expensive or unavailable.

Impacts to fisheries were considered during the implementation phase. Because remedial activities could temporarily obstruct access to potential nearshore fishing grounds, impacts to fisheries were evaluated based on the duration of remedial activities. Alternative 2 could affect nearshore fisheries in the MSU over a period of about 2.7 years. Implementation delays could occur from short-term interruptions by vessel transit and moorage. Coordination with Port of Seattle, Elliott Bay Harbor Master, and CMS would help prevent the remedial activities from impeding navigation and commerce. Dredging and capping near Pier 2 could affect CMS terminal operations for two months.

Institutional controls for shoreline activities have been implemented through signage and fencing. Institutional controls for maritime activities, such as a no-anchorage designation in a commercial harbor, would require a rulemaking by the Corps and Coast Guard and would reduce anchorage areas for commercial vessels.

5.3.2.7 Cost

The total cost of the removal alternative is $6,833,000, including a capital cost of $4,661,000 and long-term (30 years) monitoring and maintenance costs of $2,172,000 (see **Appendix F**). The cost estimate is based on use of a vortex hydraulic dredge (Eddie Pump™). Implementation of this alternative requires dredged sediment disposal. The additional costs for various disposal options are provided in **Section 5.4**, Evaluation of Disposal Site Alternatives.

5.3.3 Alternative 3—Capping

5.3.3.1 Overall Protection of Human Health and the Environment

Alternative 3a would provide long-term protection of human health and the environment by physically isolating all MSU sediments with contaminant concentrations in excess of the SQS chemical criteria. This alternative protects the environment by providing approximately 100 acres of clean (background concentrations) material to separate the benthos, water column and fish from contaminated sediments and provide clean substrate for aquatic habitat. This alternative would reduce long-term risks to human health from seafood ingestion by reducing virtually all exposure of fish and shellfish to site-related contaminants. Residual human health risks associated with site-related contaminants would be approximately 1 in 100,000 (2.5E-05) for capping to SQS. Therefore, **Alternative 3a** would reduce site risk by 95 percent.

Alternative 3b would provide long-term protection of human health and the environment by physically isolating only the most contaminated sediments (i.e., exceeding the CSL). This alternative protects the environment by using a layer of clean material to separate biota and the water column from the most-contaminated sediments and providing a 50-acre area of clean substrate for aquatic habitat.

Alternative 3b would reduce long-term risks to human health from seafood ingestion by reducing the exposure of fish and shellfish to the most-contaminated sediments. Residual human health risks associated with remaining site contaminants less than the CSL would be approximately 1 in 10,000 (specifically, 6.6E-05), an 86 percent risk reduction.

Capping is expected to have minimal short-term and no long-term impacts to threatened or endangered species.

5.3.3.2 Compliance with ARARs

Both **Alternative 3a and 3b** would meet ARARs. **Alternative 3a** would comply with the SMS by capping contaminated sediment exceeding SQS with clean materials (likely at background chemical concentrations). **Alternative 3b** would comply with the SMS by capping contaminated sediment exceeding CSL with clean materials meeting SMS chemical criteria. The residual risk associated with the remediated site would be approximately 1 in 100,000 for capping to SQS (2.5E-05) and 1 in 10,000 for capping to CSL (6.6E-05). Risk would meet the NCP risk management range of 1 in 10,000 to 1 in 1,000,000 (1E-04 to 1E-06).

Capping (and dredging near CMS) would be performed to minimize the potential for short- and long-term water quality exceedance and restore the sediment quality such that it provides productive benthic habitat; thus, the remedial actions would satisfy the substantive requirements of the Clean Water Act under Sections 401 and 404(b)(1). A Section 404(b)(1) and Clean Water Act evaluation would be performed to assess environmental impacts and impact avoidance, minimization, or mitigation. As required by the Endangered Species Act of 1973, the remediation would restore habitat available to endangered or threatened species (MSU provides habitat for salmonid species proposed for federal protection). State ARARs for water quality (specifically, WAC 173-201A-100) may not be met for TSS during capping if no dilution zone is allowed.

Implementation of the capping alternative would comply with applicable substantive requirements for construction in waters (i.e., Hydraulic Code Rules and Shoreline/Coastal Zone Management Acts) by ensuring no loss of fish and shellfish production over the long-term. Activities would meet substantive requirements of the Rivers and Harbors Appropriations Act, because no permanent obstructions or alteration of navigable waterway would occur.

The remedial action would be selected, designed, and coordinated with appropriate agencies to ensure appropriate uses of the waterway are maintained, chemical-, location-, and action-specific ARARs are met, and goals of adjacent cleanup actions are accommodated.

5.3.3.3 Reduction in Toxicity, Mobility, or Volume of Contaminants

The mobility of the contaminants and contaminated sediment would be reduced by a cap of clean sediment. A reduction in mobility would be achieved by physical isolation rather than treatment. The cap would reduce contaminant mobility by increasing the distance from the contaminated sediments to the water column and providing an overlying layer of clean sediments that can adsorb dissolved contaminants, thereby impeding release via diffusion. In addition, burial of the contamination would create a depth buffer between the deeper layer of contaminated sediments and disturbances that may resuspend them (e.g., bioturbation, anchor drag). Monitoring and maintenance of the cap would be required to ensure that physical isolation of the contaminants is maintained. No reduction in toxicity or volume of contaminated sediments would occur; however, isolation of sediments would limit further impacts to human health and the environment.

5.3.3.4 Short-Term Effectiveness

Both **Alternative 3a and 3b** present virtually no short-term risk to human health and biota from exposure to dredged sediments because little sediment volume would be dredged. **Alternative 3a** constitutes less risk to worker safety from work hazards because little heavy hazardous equipment (i.e., dredging equipment) would be used. **Alternative 3b** may represent slightly greater risk because operation of dredging equipment for a period of about two months would be required.

Dredging and capping would cause a short-term loss of aquatic habitat (about 464,000 square yards or 96 acres under **Alternative 3a** and 228,000 square yards or 47 acres under **Alternative 3b**) and biota; however, habitat and associated biological communities would improve over what currently exists after clean cap sediments are distributed over the entire MSU area.

The severity of short-term water quality impacts was primarily evaluated based on the volume of material dredged and the dredge method used. **Alternatives 3a and 3b** would pose practically no impacts to water quality from dredging because only 3,500 cubic yards would be dredged. A hydraulic vortex dredge and pipeline was assumed to be used. This method would minimize resuspension during dredging. Dredged sediment would be placed in a deeper area of the MSU and capped with the rest of the site for disposal.

Alternative 3a and 3b cap placement would cause short-term water quality impacts from suspended sediments as the cap material disperses through the water column. Additional water quality impacts could occur from the resuspension of contaminated sediments by the impact of cap material. The extent of short-term impacts was evaluated based on the cap area and the operable depths (i.e., work at greater depths is more difficult, would affect more water column during capping, and disturb a larger sediment area during capping). Because virtually the entire site would be capped to achieve SQS to a maximum depth of –255 ft MLLW, **Alternative 3a** would have a potential for water quality impacts (primarily TSS) during cap placement related to acreage and depth. Because roughly half the site would be capped to achieve CSL to a maximum depth of –240 ft MLLW, **Alternative 3b** would also have a potential for water quality impacts. These water quality impacts may violate state water quality regulations for TSS, if no dilution zone is allowed.

The implementation period for **Alternative 3a** is about 5.1 years and about 3.7 years for **Alternative 3b**. The length of implementation is determined by the assumed availability of cap material (i.e., using material available through Corp maintenance dredging projects only).

5.3.3.5 Long-Term Effectiveness and Permanence

Both **Alternatives 3a and 3b** would achieve an acceptable degree of long-term remedial effectiveness and permanence because sediment that exceeds the SMS (SQS and CSL, respectively) would be capped and a small area near the CMS terminal would be dredged prior to capping. The potential for reintroduction of contaminants into the MSU from post-remedial sources (specifically, capped areas and the intermediate groundwater discharge zone) is low; capping is recognized as an effective chemical containment technology.

Capped sediment presents a low potential for confinement failure. Areas of potential confinement failure are limited to steep (greater than 20 percent) slopes. About 28 percent of the SQS exceedance area has slopes ranging from 18 to 21 percent; 35 percent of the sediments exceeding CSL are on slopes of 18 to 21 percent. The permanence of sediment isolation in capped areas could also be affected by seismic and physical disturbances such as anchor drag. In general, the MSU is in a geotechnically stable area; however the area may be subject to seismic disturbance. Within the MSU, water circulation and wave energy at depths greater than –30 feet MLLW (91 percent of the SQS exceedance area or 88 percent of the CSL exceedance area) are generally non-erosive. Engineering controls (e.g., armoring or retaining berm construction) could be incorporated into the design to maintain a cap in sloped or higher-energy areas.

The reliability of the remediation approach offered by **Alternatives 3a or 3b** would depend on monitoring and maintenance of the capped areas. All capped areas of **Alternatives 3a or 3b** could be effectively monitored and maintained long-term using current methods and technologies; however, difficulties in monitoring and maintaining a sediment cap increase with increasing area, slope, and depth. **Alternative 3a** would have 96 acres of capped sediment distributed throughout the entire MSU, ranging from shallow shoreline locations to the deepest offshore locations; **Alternative 3b** would have about 47 acres of cap.

Alternatives 3a and 3b would require institutional controls to protect capped areas from disturbances by ships and beachcombers digging in the intertidal areas of the shoreline. Maritime controls may be difficult to implement; public access controls could be difficult to enforce. These controls would be necessary and critical to the long-term effectiveness of capped areas.

5.3.3.6 Implementability

Alternatives 3a and 3b have an acceptable degree of technical implementability, although difficulties would be encountered that are inherent in controlling the placement of capping material in inaccessible (e.g., around piers), deep, or steep areas. These alternatives would achieve capping in most of the MSU and dredging in a small area.

Alternatives 3a and 3b offer a reliable technology for sediment remediation in terms of the volume of sediments either removed or contained. Both **Alternative 3a and 3b** effectively remove a small volume of contaminated sediments, and contain a large area of contaminated sediments.

Alternative 3a, implementing the largest cap area, would be difficult to monitor effectively because of the size of the area involved and the range of depths and slopes over which it will occur. **Alternative 3b**, implementing a moderate cap area, would be moderately difficult to monitor effectively.

Alternatives 3a and 3b were evaluated for the availability of capping materials and disposal sites. The total volume of capping material for these alternatives is not readily available and would require a commitment from the Corps to obtain all available capping material for about six years for **Alternative 3a** and about 4 years for **Alternative 3b**, or coordination with possibly multiple materials suppliers over several years. Dredge disposal would occur on-site, so no additional disposal facility would be needed.

Impacts to fisheries were considered during the implementation phase. Because remedial activities could temporarily obstruct access to potential nearshore fishing grounds, impacts to fisheries were evaluated based on the duration of remedial activities. **Alternative 3a** could affect nearshore fisheries in the MSU for a period of about 5.1 years and less than 4 years for **Alternative 3b**. Implementation delays could occur from short-term interruptions by vessel transit and moorage. Coordination with Port of Seattle, Elliott Bay Harbor Master, and CMS would help prevent the remedial activities from impeding navigation and commerce. Dredging and capping near Pier 2 could affect CMS terminal operations for a short period (less than two months).

Institutional controls for shoreline activities have been implemented through signage and fencing. Institutional controls for maritime activities, such as a no-anchorage designation in a commercial harbor, would be difficult to implement.

5.3.3.7 Cost

The total cost for capping to SQS is $14,851,000 (including a capital cost of $9,500,000 and long-term monitoring and maintenance costs of $5,350,000). The total cost for capping to CSL is $7,599,000 (including a capital cost of $4,846,000 and long-term monitoring and maintenance costs of $2,753,000). No additional disposal costs are associated with this alternative. Cost estimates are provided in **Appendix F**.

5.3.4 Alternative 4—Fill Area Removal and Capping

5.3.4.1 Overall Protection of Human Health and the Environment

Both **Alternatives 4a and 4b** would provide long-term protection of human health and the environment by removing or physically isolating sediments with contaminant concentrations in excess of SMS chemical criteria (SQS or CLS, respectively). Because areas of the most contaminated sediment would be removed or contained below a 3-foot layer of clean material, the water column and biota are protected from the contaminated sediments and provided with clean substrate for benthic habitat. Both alternatives would reduce the long-term risks to human health from seafood ingestion by reducing the exposure of fish and shellfish to contaminants. The residual risk associated with the remediated site would be 1 in 100,000 (5.7E-05) for fill removal and capping to SQS and 1 in 10,000 for cleanup to CSL (1.3E-04). **Alternative 4a** would reduce site risk by 88 percent; **Alternative 4b** by 72 percent.

Although water quality impacts during remediation may pose short-term adverse affects to threatened or endangered species, this alternative would provide long-term protection of habitat for these species.

5.3.4.2 Compliance with ARARs

Alternatives 4a and 4b would meet SMS by removing or capping sediments that exceed SQS **(4a)** or the CSL **(4b)**. The residual risk associated with the remediated site would be 1 in 100,000 (5.7E-05) for fill removal and capping to SQS. Residual risks following cleanup of the fill areas to CSL and capping the remaining CLS exceedances would be about 1 in 10,000 (1.3E-04). Risks would meet the NCP risk management range of 1 in 10,000 to 1 in 100,000 (1E-04 to 1E-06).

These alternatives would be performed to satisfy federal ARARs for ambient water quality during remedial actions. Because the action involves the dredging and filling of waters of the U.S., substantive requirements of the Clean Water Act under Sections 401 and 404 apply and would require meeting water quality criteria both during and following remediation and avoiding impacts to aquatic habitats by placement of fill. If impacts cannot be avoided, the project will need to demonstrate that the remedial action either minimizes or can mitigate for those impacts. As required by the Endangered Species Act of 1973, the remediation would improve habitat used by endangered or threatened species (MSU provides habitat for salmonid species proposed for federal listing). State ARARs for water quality (specifically WAC 173-201A-100) may not be met for TSS during capping if no dilution zone is allowed.

Implementation of the fill removal and capping alternative would comply with applicable substantive requirements for construction in waters (e.g., Hydraulic Code Rules and Shoreline/Coastal Zone Management Acts). Specifically, actions would not impair fish and shellfish production following remediation. Remedial activities would meet substantive requirements of the Rivers and Harbors Appropriations Act, in that obstructions or alterations of navigable waterways would be avoided.

The remedial action would be selected, designed, and coordinated with appropriate agencies to ensure that it maintains current or future uses of the bay, meets chemical-, location-, action-specific ARARs, and is consistent with the goals of adjacent cleanup actions.

5.3.4.3 Reduction in Toxicity, Mobility, or Volume of Contaminants

The mobility of the contaminants in the non-native fill areas would be reduced by removing the contaminated sediment from the MSU and placing it in a confined disposal facility.

In **Alternative 4a**, 25 percent of the area and 96 percent of the mass exceeding SQS chemical criteria are dredged. In **Alternative 4b**, 50 percent of the area and 98 percent of the mass exceeding CSL criteria are dredged.

The mobility of contaminants outside the dredged area and exceeding SQS would be reduced by a cap of clean sediment. This reduction in mobility would be achieved by increasing the distance from the contaminated sediments to the water column and providing an overlying layer of clean sediments which can adsorb dissolved contaminants, thereby impeding release via diffusion. An exception is the intermediate groundwater discharge zone, which will be dredged and capped with the least adsorbent material practicable. Monitoring and maintenance of the on-site cap and the disposal site for dredged sediments would be required to ensure that physical isolation of the contaminants is maintained.

5.3.4.4 Short-Term Effectiveness

Alternative 4a would present short-term risk to human health and biota from exposure to dredged sediments because a large volume (381,500 cubic yards) of contaminated sediment would be dredged. **Alternative 4b** also represents a short-term risk; however, less sediment (273,000 cubic yards) would be dredged. Both **Alternatives 4a and 4b** constitute risk to worker safety from work hazards because hazardous equipment (i.e., dredging equipment) would be used extensively.

Dredge and cap areas would cause a short-term loss of aquatic habitat (about 464,000 square yards or 96 acres for **Alternative 4a** and 227,000 cubic yards or 47 acres for **Alternative 4b**) and biota; however, habitat and associated biological communities would improve after placement of clean cap sediments over most of the MSU area.

The severity of short-term water quality impacts was evaluated based on the volume of material dredged and the dredge method used. The larger the dredged volume, the greater the potential for water quality impacts. Either alternative (**4a or 4b**) would pose fewer impacts to water quality if a hydraulic vortex dredge were used (presumably in conjunction with upland or nearshore disposal). If disposal at a CAD site necessitates clamshell dredging, water quality impacts would be more severe.

Alternative 4a and 4b cap placement would cause short-term water quality impacts from suspended sediments as the cap material travels through the water column. Additional water quality impacts may occur from the resuspension of contaminated sediments caused by the impact of cap material. The extent of impacts was evaluated based on the cap area and the operable depths (i.e., work at greater depths is more difficult, would affect more water column during capping, and disturb a larger sediment area during capping). Because virtually the entire site would be capped (356,000 square yards or 72 acres) to achieve SQS to a maximum depth of –255 ft MLLW, **Alternative 4a** would have a potential for extensive water quality impacts related to acreage and depth. Only half of the site is capped under **Alternative 4b** and the maximum depth is –240 MLLW, which represents less of an impact to water quality.

The implementation period for **Alternative 4a** (about 4.8) years and **Alternative 4b** (2.9 years) is largely determined by the availability of cap material.

5.3.4.5 Long-Term Effectiveness and Permanence

Both **Alternative 4a and 4b** would achieve long-term remedial effectiveness and permanence because the most contaminated sediment would be removed from the MSU (including the nearshore fill areas, a small area near the CMS terminal, and the intermediate groundwater discharge zone). Under **Alternative 4a**, the rest of the site would be capped to achieve the SQS; **Alternative 4b** would cap the remaining areas exceeding CSL. The potential for reintroduction of contaminants into the MSU from post-remedial sources (specifically, capped areas and the intermediate groundwater discharge zone) is very low; capping is recognized as an effective chemical containment technology and the intermediate groundwater discharge zone would be dredged before capping.

Capped sediments present a low potential for confinement failure. Areas of potential confinement failure are limited to steep slopes. About 28 percent of the SQS exceedance area has slopes ranging from 18 to 21 percent; around 35 percent of the CSL exceedance area has slopes between 18 to 21 percent. The permanence of sediment isolation in capped areas could be affected by seismic and physical disturbances. In general, of the MSU is in a seismically stable area. Within the MSU, water circulation and wave energy at depths greater than –30 feet MLLW (91 percent of the SQS exceedance area or 88 percent of the CLS exceedance area) are generally non-erosive. Engineering controls (e.g., armoring or retaining berm construction) could be incorporated into the design to maintain a cap in sloped or erosional areas.

The reliability of the remediation approach offered by **Alternatives 4a and 4b** would depend on monitoring and maintenance of the capped areas. All capped areas could be effectively monitored and maintained long-term using current methods and technologies; however, difficulties in monitoring and maintaining a sediment cap increase with increasing area, slope, and depth. **Alternative 4a** has a 73 acres of capped sediment with 66 acres occurring in deeper offshore locations. **Alternative 4b** will have approximately 24 acres of cap, with 17 acres occurring in deeper areas.

Both alternatives would require institutional controls to protect capped areas from disturbances by ships in the offshore and clam digging at the shoreline. Maritime controls could be difficult to implement; existing public access controls may be difficult to enforce. These controls would be necessary and critical to the long-term effectiveness of capped areas.

5.3.4.6 Implementability

Both **Alternatives 4a and 4b** have an acceptable degree of technical implementability.

Alternatives 4a and 4b offer a highly reliable technology for sediment remediation in terms of the volume of sediments either removed or contained. **Alternative 4a** effectively removes a large (382,000 cubic yards) volume of contaminated sediments and confines an additional 73-acre area of contaminated sediments. **Alternative 4b** removes a moderate volume (274,000 cubic yards) of contaminated sediment and confines an additional 24 acres of contaminated sediments.

Alternative 4a, constituting a 73-acre cap area, would be difficult to monitor effectively. **Alternative 4b**, with a 24-acre cap, could be effectively monitored.

Alternatives 4a and 4b were evaluated for the availability of capping materials and disposal sites. Capping material for **Alternative 4a** is not readily available due to the volume required (569,000) cubic yards) and would require coordination with possibly multiple materials suppliers over several years. The volume required for **Alternative 4b** (154,000 cubic yards) is readily available. A disposal site with adequate capacity for either alternative would be difficult to construct (**Section 5.4**) and existing facilities are prohibitively expensive, making this aspect of implementability poor for these alternatives.

Alternative 4a would involve large cap (73 acres) and dredge areas and a long-term (approximately 5 years) implementation schedule, thus affecting nearshore fisheries. **Alternative 4b** would have a small (24 acres) cap and implementation period that could disrupt fisheries activities for a 2- to 3-year period, depending upon timing.

Institutional controls for shoreline activities have been implemented through signage and fencing. Institutional controls for maritime activities, such as a no-anchorage designation in a commercial harbor, would be difficult to implement.

5.3.4.7 Cost

The total cost for fill removal and capping to SQS (**Alternative 4a**) is $14,363,000 (including a capital cost of $9,880,000 and long-term monitoring and maintenance costs of $4,483,000). The total cost for fill removal and capping to CSLs (**Alternative 4b**) is $6,152,000 (including a capital cost of $4,442,000 and long-term monitoring and maintenance costs of $1,710,000). These costs are based upon the use of a vortex hydraulic dredge (Eddy Pump™). *Implementation of these alternatives requires dredged sediment disposal, which is not included in the estimates for removal and capping.* The costs for various disposal options are provided in **Section 5.4**, Evaluation of Disposal Site Alternatives. **Appendix F** provides cost estimate details for this alternative.

5.4 EVALUATION OF DISPOSAL SITE ALTERNATIVES

As presented in **Section 4.3**, two CAD sites on Elliott Bay, one nearshore facility (with several configurations) adjacent to the PSR MSU, and two upland disposal sites are evaluated.

5.4.1 Confined Aquatic Disposal (CAD) Sites

5.4.1.1 Overall Protection of Human Health and the Environment

Disposal of contaminated sediments in a CAD site would provide long-term protection of human health and the environment by physically isolating sediments that exceed SMS criteria. Because the sediment would be contained below a layer of clean material, this alternative protects the environment by separating the water column from the contaminated sediments and providing clean substrate for benthic habitat. This disposal alternative would also reduce the long-term risks to human health from seafood ingestion by reducing the exposure of fish and shellfish to contaminants.

The degree of long-term environmental protectiveness of a CAD site is limited by the susceptibility to cap disturbance (e.g., bioturbation and anchor drag) and the difficulties of effective monitoring needed to ensure long-term isolation of contaminants. Because a deep water facility is less accessible, the cap may not be easily inspected and because long-term monitoring would be relatively infrequent (typically every few years after the first year), damage may go undetected for periods of time.

As explained in **Section 5.4.1.4**, Short-Term Effectiveness, construction of a CAD facility could cause water quality impacts at the disposal site. Therefore, short-term adverse impacts could affect threatened or endangered aquatic species by exposure to contaminants during disposal in the vicinity of the CAD site.

5.4.1.2 Compliance with ARARs

CAD disposal would comply with SMS by confining sediment with clean materials meeting SQS criteria. CAD development would be conducted to meet federal ARARs for ambient surface water quality during construction. Because this alternative involves the discharge of fill materials to waters of the U.S., substantive dredge and fill requirements of the Clean Water Act under Sections 401 and 404 would be met to demonstrate that disposal in an aquatic environmental was the least environmentally damaging alternative and that implementation would be conducted such that water quality impacts were minimized. Remedial activities would also be performed to meet substantive requirements of the River and Harbors Appropriations Act such that no permanent obstruction or alteration of a navigable waterway would result. In addition, a Section 404(b)(1) and Clean Water Act evaluation would be performed to assess environmental impacts and associated mitigation. State ARARs for water quality (specifically, WAC 173-201A-100) would not likely be met for TSS during disposal if no dilution zone is allowed.

All applicable state and local permits would be obtained for off-site activities and disposal, including Coastal Zone Management Act, Shoreline Management Act, Hydraulic Code Rules, CWA Section 404, and CWA Section 401, and authorization under Rivers and Harbors Act.

5.4.1.3 Reduction in Toxicity, Mobility, or Volume of Contaminants

Contaminant mobility would be reduced by a clean sediment cap on the CAD site. This reduction in mobility would be achieved by increasing the distance from the contaminated sediments to the water column and providing an overlying layer of clean sediments that can adsorb dissolved contaminants, thereby impeding release via diffusion. Diffusion could result in a release of contaminants because the cap over the impacted sediments is not impermeable. Monitoring and maintenance of the cap would be required to ensure that physical isolation of the contaminants is maintained.

5.4.1.4 Short-Term Effectiveness

Short-term environmental risks are associated with disposal at a CAD site. Implementation of this disposal alternative requires the use of a clamshell dredge for MSU dredging (costing of alternatives assume the use of a hydraulic vortex dredge), a barge to transport the excavated sediment to the disposal site, and a clamshell dredge to place the sediment into the CAD site. These methods are necessary to minimize contaminant loss by maintaining approximate *in situ* sediment density for faster settling and less spreading of the material upon placement. Dredging, transporting and placing the sediment in this manner poses short-term risks to the environment due to the potential for water quality impacts at the point of dredging and disposal and site recontamination.

The clamshell dredging method can result in moderate to high sediment resuspension rates, thereby potentially increasing TSS and contaminant concentrations in the water column during the dredging action. Sediment loss during clamshell dredging may also result in site recontamination. Transport of the dredged sediment by barge also has the potential for release of contaminated sediments during transport.

Placement by split-hull barge results in substantial potential for contaminated sediment resuspension. In addition, an evaluation of discharging sediment with a split-hull barge into 200 feet of water indicates a deposition pattern of 2,000 feet in diameter may occur (see **Appendix A**). Based on this, CAD Site 1 requires placement with a clamshell to keep the sediment within the target zone. CAD Site 2, being shallower, has a smaller deposition pattern (1,000 feet in diameter) and would likely result in a smaller quantity of material falling outside the disposal site. Based on the depths and contaminant concentrations in the sediment, use of barge dumping for depositing material into the CAD sites was not considered environmentally protective because of the potential for some loss of highly contaminated material. Placing sediment into the disposal site by clamshell would result in fewer suspended solids and contaminant concentrations in the disposal site water column or surrounding sediments.

The use of clamshell dredge and barge transport also poses exposure risks to remediation workers because of the potential for dermal contact with contaminants during excavation and transport of the sediment. Remediation workers' exposure would be minimized through the use of appropriate controls, equipment, and protective clothing. Industrial accidents are most likely to occur during sediment placement into the CAD site.

The CAD construction would initially disturb 30 to 35 acres of the habitat and displace biological communities. Subsequently, opportunistic species would colonize this coarser-grained environment. However, as finer-grained silts cover the coarser-grained material over time, the habitat would change to reflect the biological makeup of the surrounding area resulting in long-term environmental protection.

Because CAD disposal requires the use of a clamshell dredge for sediment removal and placement purposes, this disposal alternative requires about a one year implementation period (i.e., greater than an alternative incorporating hydraulic dredging and split-hull barge placement).

This disposal option would result in removal of some fishery area during construction due to barge and tug traffic near the disposal site.

5.4.1.5 Long-Term Effectiveness and Permanence

The long-term effectiveness of confined aquatic disposal is dependent upon its ability to effectively isolate contaminants and the ability of the overlying cap to provide a suitable habitat for marine organisms. Because the capped surface would be composed of native sediment, it would provide suitable habitat for recolonization of benthic biological communities from the surrounding area. This disposal method relies on confinement of consolidated contaminated sediment. The long-term effectiveness of a CAD disposal site is similar to that of capping except that the site footprint is known, the area of contamination is smaller (less than 40 acres depending upon the sediment volume to be disposed) and the site is deeper (less subject to bottom disruption events such as anchor drag).

The permanence of contaminant isolation is dependent upon a number of factors, including stability of the disposal area, and disturbance to the cap such as bioturbation, anchor drag, currents, and other hydrological impacts. Both CAD sites provide high static stability and low failure risk to seismic forces because of the low native slope (6 percent or less). In addition, both sites generally have weak bottom currents resulting in a low risk of erosion of the cap. CAD Site 1 depths range from -155 to -200 feet MLLW and CAD Site 2 depths range from -80 to -120 feet MLLW. This disposal option is reliable as long as the CAD cap remains intact. Institutional controls to prevent anchoring on the CAD site will be necessary to ensure the integrity of the CAD.

To ensure that the CAD facility maintains physical integrity for at least 30 years and achieves long-term effective containment, inspections, monitoring, and maintenance would be performed. Periodic monitoring would be conducted to evaluate contaminant diffusion through the cap. For the purpose of cost comparisons, it was assumed that cap monitoring would consist of surface and core samples every three acres. Sampling would be performed every other year and maintenance would be performed as required. In addition, the CAD cap would be inspected for physical damage. As explained previously, comprehensive inspections by divers are only feasible at depths less than -120 feet MLLW; deeper areas would require remote inspection by camera. CAD Site 1 is deeper than -120 feet MLLW; CAD Site 2 is shallower than -120 feet MLLW.

5.4.1.6 Implementability

The construction of the proposed CAD sites is technically feasible because the depths are less than -200 feet MLLW (the maximum depth for dredging). However, the ease of construction decreases with increased CAD depth; specifically, the ability to control material removal and placement is diminished. CAD Sites 1 and 2 have depths up to -200 and -120 feet MLLW, respectively.

The availability of potential CAD sites is limited due to the depth of relatively flat-bottomed areas and steep slopes of the shallower areas. Only two potential CAD sites were found.

Use of CAD Site 1 would require a survey to map the location of the PCB sediment placed by the Corps Waterways Experimental Station. CAD Site 1 must not be located in the same area to avoid contaminating the CAD capping material.

CAD Site 2 is exposed to southerly fetch and storm conditions that could decrease the accuracy of placement. Therefore, specialized engineering and operational controls may be required to implement this alternative. In addition, construction would need to accommodate adverse weather, since the implementation period would extend over a year.

Although no long-term impacts to fisheries would result from the implementation of CAD disposal, short-term impacts to fishing activity could occur during CAD construction from water quality impacts in the immediate vicinity of the CAD site, and barge moorage and traffic associated with construction activities. Additional implementation complications may be encountered due to short-term interference with vessel traffic and vessel moorage in Elliott Bay. CAD construction would be completed in a manner to accommodate vessel traffic (additional lighting to avoid nighttime collisions, minimizing space between barges to reduce area where navigation may be impeded, expediting construction to reduce the period obstacles are present), and coordination with the Port of Seattle and the Elliott Bay Harbor Master would be necessary to prevent impedances to navigation and commerce.

Implementation of CAD sites requires minimal construction materials, because the capping material will be provided by CAD site dredging.

Monitoring a CAD site is difficult because of its depth. Monitoring must use remote techniques such as cameras or cores and each of these methods provides for only partial inspection of the overall area.

5.4.1.7 Cost

The cost to dispose of sediment into a CAD site is estimated at $18 per cubic yard (**Appendix F**). Disposal costs range from $6 million to $8 million, depending on cleanup alternative. **Table 5-1** provides the cost estimates for disposal of sediment in Alternatives 2, 4a, and 4b.

5.4.2 Nearshore Disposal Sites

5.4.2.1 Overall Protection of Human Health and the Environment

Disposal of contaminated sediments in a nearshore site would provide long-term protection of human health and the environment by physically isolating sediments that exceed SMS criteria. Contaminated sediment would be isolated by an engineered confinement system consisting of a riprap and sand infill berm to serve as a barrier to sediment and contaminant migration to the MSU water column and a 3- to 5-foot cap of clean material to ensure contaminant isolation from the upland area. The disposal site can be easily monitored, inspected, and maintained to achieve long-term protectiveness.

Short-term impacts to threatened or endangered species in the vicinity of the MSU could result during CND facility construction due to water quality impacts from construction activities.

Long-term impacts to threatened or endangered species could also result from nearshore disposal. The footprint of the disposal site would encompass approximately 16 acres of shallow subtidal area, resulting in a loss of fish habitat. The area lost, however, is currently highly contaminated, providing low-quality habitat for fish. The construction of a nearshore disposal facility would increase the lineal shoreline by 700 to 900 feet (depending upon configuration) and create approximately 4 acres of high-quality shallow subtidal and intertidal habitat.

5.4.2.2 Compliance with ARARs

Nearshore disposal would meet SMS by confining sediment with clean materials meeting SQS criteria. The alternative would be performed to meet federal and state ARARs for ambient surface water quality during the construction of the berm and substantive permit requirements for the discharge of treated relief water from sediment dewatering operations. In addition, substantive requirements for construction near a shoreline would be met. As required by the Endangered Species Act of 1973, the remediation action would be performed so as to conserve endangered or threatened species (MSU provides habitat for some salmon species proposed for federal listing). In addition, a Section 404(b)(1) and Clean Water Act evaluation would be performed to assess environmental impacts and show how such impacts would be avoided, minimized, or mitigated.

5.4.2.3 Reduction in Toxicity, Mobility, or Volume of Contaminants

The mobility of the contaminants would be reduced by the berm and cap, which serve to isolate the contaminated sediment from the MSU water column and PSR Upland Unit. This reduction in mobility would be achieved by physical isolation rather than chemical treatment. Monitoring and maintenance of the confinement system would be required to ensure that physical isolation of the contaminants is maintained.

The confinement berm is not impermeable. The potential exists for contaminants to migrate through the berm. However, release of significant quantities of contaminates via this mechanism is unlikely because contaminated material would be maintained in a saturated anaerobic condition which will minimize contaminant transfer from the sediment to the porewater. Groundwater flux is low and the berm will also provide some attenuation of dissolved contaminants.

5.4.2.4 Short-Term Effectiveness

Implementation of a nearshore disposal site could result in short-term impacts to human health and the environment.

The potential for short-term exposure of remediation workers is low because contaminated sediments would likely be hydraulically dredged, then transported and placed into the disposal site with a floating pipeline. This method would result in minimal worker contact with the dredged contaminated sediments. Remediation workers' exposure would be minimized through the use of appropriate controls, equipment, and protective clothing.

Nearshore disposal could result in short-term water quality impacts at the disposal site, but because contaminated sediments will be dredged and transported in a confined manner (i.e., hydraulic dredging and floating pipeline transport), turbidity is expected to be low during dredge and transport operations. Localized turbidity may be experienced, however, during the construction of the berm as fill material is being dumped through the water column.

It was assumed that nearshore disposal would involve hydraulic dredging and transport of the sediment to the adjacent disposal facility, which would result in this alternative requiring a short (less than 8 months) implementation period.

This disposal option would result in the loss of 14 to 17 acres of shallow subtidal habitat and fishing grounds.

Industrial accidents are most probable during nearshore berm construction due to the use of heavy equipment.

5.4.2.5 Long-Term Effectiveness and Permanence

Confinement of dredged sediments in a nearshore disposal facility would provide long-term protection to human health and the environment. Nearshore confined disposal sites using containment berms and cap covers are considered to be a reliable and proven method for confinement of contaminated sediments, and are included in Ecology's Standards for Confined Disposal of Contaminated Sediments (**Parametrix 1990**). Because the aquatic and upland portions of the disposal site are accessible, the site could be easily monitored and inspected to determine its integrity and could be easily maintained to ensure its long-term effectiveness.

Construction of a nearshore disposal facility near PSR would allow the use of the filled area to be compatible with adjacent upland usage (i.e., habitat, public access, intermodal yard storage). Use as a storage area would require that the structural integrity of the site remain intact, providing good assurance that long-term monitoring, inspection, and maintenance would be accomplished.

The permanence of sediment isolation is affected by the static and seismic stability of the engineered confinement system. Although the berm and cap cover would be constructed with a design life of 30 years to provide long-term static stability, the nearshore areas could be susceptible to seismic disturbance as explained for Alternative 2. This susceptibility to seismic disturbance results in a potential for containment failure.

Nearshore disposal has the potential to release contaminants back into the environment (e.g., through leaching and migration of contaminants from the disposal site towards the surface waters of the MSU); however, the site can be easily monitored, inspected and maintained to provide long-term effectiveness.

The different configurations considered for the disposal site would cover approximately 14 to 17 acres (including the berm) of nearshore area. Habitat losses of shallow subtidal areas would result from the filling of these sites that now provide low quality habitat for native marine communities. The present ecological values of these sites are limited by existing contamination. The outer slopes of the retaining berm could be designed to provide good habitat substrates and the overall condition of habitat in the area would be improved by the remedial action.

Institutional controls to limit the use of the nearshore area to industrial purposes are considered reliable.

5.4.2.6 Implementability

Construction of a nearshore disposal site is technically feasible. Contained nearshore disposal is a proven technology and implementation is anticipated to be straightforward. Materials for berm construction are available. Riprap would need to be barged in from a quarry on the Kitsap peninsula. Sand could be obtained from the Steilacoom sand pit. Both borrow sources have water access.

The proposed disposal site is proximal to the MSU, providing convenient transport for contaminated sediments. Although significant effort would be involved in constructing a retaining berm, the fill area is shallow and access to the sites from the aquatic side is good, creating favorable construction conditions. The proposed site is also relatively flat, making berm construction easier.

Impacts to tribal fishing activity near the MSU could occur during CND facility construction (if construction overlaps with fishing season) due to construction-related vessel traffic and moorage, and water quality impacts. Long-term impacts to fisheries would also occur with nearshore disposal. The footprint of the disposal site would encompass approximately 14 to 17 acres of shallow subtidal area, resulting in a loss of fish habitat and nearshore area available for tribal fishing. The area lost, however, is currently contaminated and provides low-quality habitat for fish. In addition, the construction of a nearshore disposal facility would increase the lineal shoreline by 700 to 900 feet (depending upon configuration) and create approximately 4 acres of clean shallow subtidal and intertidal habitat.

The construction of a CND facility would have no long-ranging impacts on water-dependent industry because there is no current or planned future use of the designated nearshore site that would require water access.

Monitoring of the nearshore facility is not difficult. Virtually 90 percent of the cap and retaining berm could be visually inspected.

Site availability for nearshore disposal is extremely limited. Of the numerous potential sites available, only the Lockheed site had potential administrative feasibility.

This disposal site and method of disposal is reliable. Nearshore disposal has been used at other sites with good success. A preliminary geotechnical evaluation has shown this site to be stable given the proper design.

Construction of a nearshore facility could occur within an 8-month period. Completion is dependent upon the amount of material to be disposed.

5.4.2.7 Cost

The cost to dispose of sediment into a nearshore site is estimated at $26 per cubic yard (see **Appendix F**). Costs range from $8 million to $11 million, depending upon the cleanup alternative selected. **Table 5-2** provides the cost estimates for disposal of sediment in Alternatives 2, 4a, and 4b.

5.4.3 Upland Disposal Sites

Because both upland sites are essentially the same distance from PSR and consist of similar land types, there are no significant differences in their evaluation against the criteria. The following discussion pertains to both upland disposal sites.

5.4.3.1 Overall Protection of Human Health and the Environment

Disposal of contaminated sediments in an upland confined disposal facility would provide long-term protection of human health and the environment by removing contaminated material from the aquatic environment and physically isolating sediments that exceed SMS criteria. Contaminated sediment would be confined in an above-ground, double-lined basin and capped with clean soil. This confinement system and the associated monitoring would virtually eliminate the potential for sediment or contaminated leachate to escape undetected into the environment.

Sediment disposal in an upland facility would not result in short- or long-term adverse impacts to threatened or endangered species.

5.4.3.2 Compliance with ARARs

Upland disposal would meet SMS by removing the contaminated sediment exceeding chemical criteria from contact with marine surface water. The alternative would be performed to meet substantive permit requirements and water quality standards for the discharge of treated relief water from sediment dewatering operations. In addition, the drying ponds associated with dewatering would be monitored and treated, if necessary, to ensure no air releases exceeding standards provided by WAC 173-460. The dewatered sediment would be handled and disposed of in accordance with the following applicable federal and state waste regulations: Land Disposal Restrictions (40 CFR 268), Dangerous Waste Regulations (WAC 173-303), and Minimum Functional Standards for Solid Waste Handling (WAC 173-304). All applicable permits would be obtained as required for off-site remedial and disposal actions.

Modified elutriate tests (METs) were performed to predict the effluent quality from nearshore dewatering operations prior to upland disposal. The test results indicate that the discharge of separable dredge water could result in exceedances of federal marine acute ambient water quality criteria (AWQC) for two LPAHs (phenanthrene and napthalene). To protect water quality during the dewatering of dredged sediment, the separable dredge water would be detained using an oil boom and/or activated carbon filter and treated prior to discharge. Water quality sampling would be performed to ensure contaminant levels were acceptable.

5.4.3.3 Reduction in Toxicity, Mobility, or Volume of Contaminants

The mobility of the contaminants would be effectively reduced by the liner and soil cap containment system that serves to isolate the contaminated sediment from the environment. This reduction in mobility would be achieved by physical isolation using impermeable liners rather than treatment. Volumes of contaminated material in the aquatic environment would be substantially reduced. Exposure pathways would be eliminated. Monitoring and maintenance of the confinement system would be required to ensure that physical isolation of the contaminants is maintained.

5.4.3.4 Short-Term Effectiveness

Significant short-term human health and environmental exposure risks are associated with upland disposal as a result of substantial material handling that is required to remove, dewater, load, transport, and unload the contaminated sediment.

Approximately 12,000 truckloads of sediment would be transported from the MSU to the upland disposal site. The Harbor Island area is a heavily trafficked industrial complex, and the additional truck traffic would increase congestion. Contaminants could be spilled from trucks during operations or highway accidents. Spills could result in exposure of the general public to the contaminated sediment and cleanup could result in minor health risks to workers. Exposure potential can be reduced by truck bed liners, although spillage could still result from highway accidents. Human health risks are also associated with the potential for worker contact with the contaminated sediment during upland dewatering operations and placement at the confinement facility.

Upland disposal would result in short-term risks to the environment due to the potential for contaminant release and water quality impacts during dewatering operations. To minimize the potential for contaminant release to Elliott Bay, separable water would be collected for on-site treatment before discharge. At the upland disposal site, any additional water collected during sediment placement would be confined by liners, collected, and treated. Releases of PAHs to air could also occur during dewatering and handling, especially during warm days. Traffic accidents could release contaminated sediment along roadsides.

Upland disposal would require time to allow dewatering; however, sediment transport capacity is the limiting factor for determining the implementation period, which could range from 8 to 11 months. This option would not result in any loss of marine habitat. Terrestrial loss of habitat is not significant since the upland areas are planned for development in the near future. Both upland sites are zoned for industrial use.

No impact to fisheries would occur during upland disposal.

Upland disposal has the potential to result in industrial accidents to workers from sediment loading, transport, offloading, grading and disposal site construction.

5.4.3.5 Long-Term Effectiveness and Permanence

Confinement of dredged sediments in an upland disposal facility would provide long-term protection to human health and the environment. Upland confined disposal sites using liners, cap covers, and leachate collection systems are considered to be a reliable and proven method for confinement of contaminated sediments, and are included in Ecology's Standards for Confined Disposal of Contaminated Sediments (**Parametrix 1990**).

Few long-term environmental risks are associated with upland disposal. An above-ground, double-lined, monitored confinement cell virtually eliminates the potential for sediment or contaminated leachate to escape undetected into the environment A small potential for the release of leachate by liner leakage (typically through the seams) could impact groundwater. This environmental risk would be reduced by the use of a double liner.

The upland disposal facility would be constructed with a 30-year design life. Monitoring would be employed to evaluate the physical integrity of the containment system to ensure long-term effectiveness. Because the upland disposal site would be aboveground, thorough inspections and monitoring could be easily performed.

Although confinement greatly reduces the potential for contact, inhalation, and ingestion of contaminated materials, site access would need to be controlled for public safety to ensure the integrity of confinement was maintained and to reduce the potential for human exposure to contaminants. The long-term effectiveness could be affected by future use of the surrounding area. Future use is unknown at this time, although the area currently is zoned for industrial use.

The adequacy of institutional controls to prevent intrusion onto the site may be low due to minimal supervision of the upland site and its attractiveness as a play area.

5.4.3.6 Implementability

Upland disposal is highly reliable. Construction of an upland disposal site uses the same technology as landfill construction, which is well proven. However, significant difficulties are associated with this disposal alternative because upland disposal requires the construction of a dewatering area to dry the sediment before it can be loaded and transported to the upland site.

Two dewatering cells, approximately 2 to 3 acres in size, would be required. This area of undeveloped land is currently not available on the PSR site. The PSR upland area is covered with railroad tracks and underlain with an extensive storm drain system. The area with the most open space is immediately north and south of the maintenance building. One possible configuration would be to construct dewatering ponds in this area and relocate the maintenance building. Public access would be precluded during dewatering. Use of this area for dewatering, truck loading, and transport would be very disruptive to the ongoing operation of the intermodal yard.

Dewatering the sediments would also require a substantial implementation period, which would result in dredge standby time, increased costs, and a longer remediation schedule. Approximately 8 to 11 months would be required just to transport the sediment to the upland disposal site, depending upon the cleanup alternative selected.

Implementation of upland sediment disposal would result in no reduction in fisheries or impact water-related industries.

Monitoring of an upland disposal site has few difficulties. The site is virtually 100 percent accessible for visual inspection. Leachate collection systems provide easy monitoring of the confinement liners.

Upland sites are limited. Open space is highly valued for development and is not available near PSR. The only open space available is located in less-developed areas at moderate distances from PSR.

5.4.3.7 Cost

The cost to dispose of sediment into an upland site is estimated at $45 per cubic yard (see **Appendix F**). Upland disposal costs range from $14 million to $20 million, depending upon the alternative selected. **Table 5-3** provides the cost estimates for disposal of sediment in **Alternatives 2, 4a, and 4b**.

5.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section provides a comparative analysis and numerical evaluation of the alternatives based on a composite score using the seven criteria discussed in **Section 5.2**. Project-specific criteria are incorporated within these seven criteria. The results of the relative ranking for each sediment alternatives and disposal options are shown in **Tables 5-6 and 5-7**, respectively, and the ranking by individual criterion that contributed to the overall score is provided in **Appendix G**.

Please see **Table 4-5** for a summary of alternative features, including dredge volume, disposal capacity requirements, cap area, and cap material volumes.

5.5.1 Overall Protection of Human Health and the Environment

The degree of protectiveness for human health and the marine environment has been determined by the anticipated concentration of contaminants in the MSU surface sediment following remediation and assumed lower contaminant concentrations resulted in higher sediment quality. An improved benthic habitat quality would lessen the exposure of fish and shellfish to site-related contaminants and, thereby, reduce the risk to human health from Elliott Bay seafood ingestion. Therefore, the highest degree of protectiveness would be provided by capping with material characterized by background contaminant concentrations, a moderate degree of protectiveness would be provided by dredging to SQS, and the lowest degree of protectiveness would result from dredging to CSLs. **The following is a list of the alternatives ranked from most protective to least protective (see Table G-1 for numeric ranking) based upon the remedial actions employed (i.e., amount of capping or dredging performed) and the resulting sediment quality**:

- Alternative 3a—Capping to SQS;
- Alternative 4a—Fill Removal and Capping to SQS;
- Alternative 3b—Capping to CSLs;
- Alternative 4b—Fill Removal and Capping to CSLs;
- Alternative 2—Dredging to CSLs; and
- Alternative 1—No Action.

5.5.2 Compliance with ARARs

All alternatives, with the exception of the No Action alternative, comply with ARARs and meet the federal risk requirements (see **Table G-2** for numeric ranking).

5.5.3 Reduction in Toxicity, Mobility and Volume Through Treatment

None of the alternatives reduce toxicity, mobility or volume through treatment. However, all alternatives, excluding Alternative 1—No Action, reduce contaminant mobility through confinement (see **Table G-3** for numeric ranking).

5.5.4 Short-Term Effectiveness

The short-term effectiveness of an alternative is related to the associated water quality impacts, potential for worker injury, risk of human and biota exposure to contaminants (including exposure of threatened or endangered species), and habitat loss during the implementation of the remedial action. Remedial alternatives that involve dredging a greater volume of contaminated sediment would result in greater potential for water quality impacts, human exposure to contaminants, and worker injury resulting from the use of dredging machinery (which is more mechanically complex than machinery required for capping). Short-term habitat loss occurring during remediation would be greater with alternatives that encompass a larger cleanup area (i.e., SQS alternatives would disturb a larger area than CSL alternatives). The duration of these short-term human health and environmental risks is determined by an alternative's implementation period. Disruption of fisheries activities or other water-dependent uses is considered within the context of duration. Therefore, greater short-term effectiveness is achieved when less contaminated sediment is dredged, a smaller area is disturbed during remedial activities, and the alternative is completed in a shorter implementation period.

Alternative 1—No Action has the best short-term effectiveness because it has no dredging, no habitat disturbance, and no implementation period. Of the remaining alternatives, Alternative 3b—Capping to CSLs has the greatest short-term effectiveness because it involves dredging the least volume of sediment, disturbs a relatively small area, and requires a moderate implementation period. Moderate short-term effectiveness is achieved by Alternative 3a—Capping to SQS, Alternative 4b—Fill Removal and Capping to CSLs, and Alternative 2—Dredging to CSLs. The least short-term effectiveness is provided by Alternative 4a—Fill Removal and Capping to SQS because it involves dredging a large volume of sediment, disturbs the greatest habitat area and requires the longest implementation period. **In summary, the following is a list of remediation alternatives ranked from highest to least short-term effectiveness (see Table G-4 for numeric ranking):**

- Alternative 1—No Action;
- Alternative 3b—Capping to CSLs;
- Alternative 3a—Capping to SQS and Alternative 4b—Fill Removal and Capping to CSLs;
- Alternative 2—Dredging to CSLs;
- and Alternative 4a—Fill Removal and Capping to SQS.

5.5.5 Long-Term Effectiveness and Permanence

Long-term effectiveness is based on the reliability of the remedy (i.e., ensured long-term protectiveness provided by dredging or capping), the associated degree of monitoring and maintenance necessary, and the adequacy of institutional controls required to protect the remedy. No-anchor zones would need to be established for all alternatives (excluding the No Action alternative) to protect the integrity of caps in deep water areas, and the adequacy and reliability of such no-anchor zones would be equally effective for the alternatives; however, size of the no-anchor areas varies. Size differentials will be addressed as part of implementability. Although capping is a reliable method of containment, removing contaminated sediment from the MSU and placing it in a disposal facility provides an even higher degree of reliability and permanence because of the smaller footprint of the contaminant distribution left in the aquatic environment. Contaminated sediment consolidated and confined in an engineered disposal facility is also easier to inspect, monitor and maintain than an in-place cap (primarily because of the controlled location, and ease of access and efficacy of monitoring tools in the case of CND or upland disposal. Therefore, greater long-term effectiveness is achieved when more of the contaminated sediment is removed and less when the remedy relies on an in-place cap for confinement.

The greatest long-term effectiveness and permanence is provided by Alternative 2—Dredging to CSLs because it involves the smallest cap area and a large reduction of contaminants left in place. Alternative 4b—Fill Removal and Capping to CSLs includes a slightly larger cap and less sediment removal, and would achieve the next best long-term effectiveness. Moderate long-term effectiveness is provided by Alternative 3b—Capping to CSLs and Alternative 4a—Fill Removal and Capping to SQS. Alternative 3a—Capping to SQS involves the largest cap and removes a small amount of sediment making it even less effective. Alternative 1—No Action has the lowest degree of long-term effectiveness because it provides no remedy and the contaminated sediment remains in the aquatic environment, presenting risks to human health and the environment. **The following is a list of the alternatives ranked from highest long-term effectiveness to least long-term effectiveness (see Table G-5 for numeric ranking):**

- Alternative 2—Dredging to CSLs;
- Alternative 4b—Fill Removal and Capping to CSLs;
- Alternative 3b—Capping to CSLs and Alternative 4a—Fill Removal and Capping to SQS;
- Alternative 3a—Capping to SQS; and
- Alternative 1—No Action.

5.5.6 Implementability

Evaluation of implementability includes examining the ease of construction, the reliability of the technologies involved, the ability to monitor the effectiveness of the alternative, the availability of capping material, the volume of sediments requiring disposal, the alternative's impact to fisheries, and the ability to create no-anchor zones within Elliott Bay. In general, alternatives involving more capping (and, therefore, less dredging) are considered easier to construct, but are considered more difficult to implement with increasing depth because of greater uncertainty in material placement, and more difficult to monitor effectively because of the depth and the size of the cap. In addition, construction of a cap will require designation of a no-anchor zone over the cap. Size of the cap was considered in the ease of implementation of such an institutional control (smaller = easier because of fewer impacts to shipping). Capping-intensive alternatives also require more capping material (which is a time-limited resource, and thus increases the cap construction time), but require less disposal capacity (which reduces the administrative issues associated with siting and permitting a facility because of the small disposal volume). Alternatives requiring a longer implementation period would have a greater impact to fisheries during implementation.

Based on these characteristics, the alternatives were ranked as follows (see Table G-6 for numeric ranking):

- Alternative 2—Dredging to CSLs;
- Alternative 4b—Fill Removal and Capping to CSLs;
- Alternative 3b—Capping to CSLs;
- Alternative 4a—Fill Removal and Capping to SQS; and
- Alternative 3a—Capping to SQS.

No implementation is required for Alternative 1—No Action.

5.5.7 Cost

The costs associated with the remedial alternatives are displayed in **Table 5-4**. The bases for these values differ: the Alternative 3 cost is all-inclusive (i.e., it accounts for disposal) and the costs for Alternatives 2 and 4 do not include dredged sediment disposal. The costs for various disposal options are provided in **Table 5-5. Given differences in disposal requirements, costs are ranked from lowest to highest (see Table G-7 for numeric ranking)**:

- Alternative 3b—Capping to CSLs
- Alternative 3a—Capping to SQS
- Alternative 4b—Removal and Capping to CSLs
- Alternative 4a—Fill Removal and Capping to SQS
- Alternative 2—Dredging to CSLs

There is no cost associated with Alternative 1—No Action.

Currently, none of the costs address the premium DNR plans to charge for use of state-owned aquatic lands. DNR's fees will affect the costs associated with the capping alternatives, as well as disposal in a CND or CAD.

5.6 COMPARATIVE ANALYSIS OF DISPOSAL OPTIONS

5.6.1 Overall Protection of Human Health and the Environment

With the appropriate monitoring and maintenance, all disposal options provide effective protection of human health and the environment by isolating contaminants. Upland disposal removes contaminants from the marine environment, and the nearshore and CAD disposal facilities provide high quality habitat (in varying amounts) for marine organisms, thereby, protecting human health.

5.6.2 Compliance with ARARs

Nearshore disposal and upland disposal comply with ARARs (if necessary, upland disposal would incorporate special design features to maintain a 10-foot separation from groundwater). CAD disposal may result in short-term water quality exceedances of TSS and several PAHs in an area greater than that accommodated by the mixing zone per WAC 173-201A-100. Therefore, state water quality ARARs may not be met during CAD disposal. See **Table G-9** for scoring details.

5.6.3 Reduction in Toxicity, Mobility and Volume through Treatment

All disposal options reduce the mobility of the contaminants by confinement. Upland disposal includes treatment of relieved dredge water and leachate resulting in a reduction in toxicity of this portion of the material. However, this toxicity reduction is minor compared to the entire contaminant mass. The volume of contaminated sediment is not reduced in any alternative. See **Table G-10** for scoring details.

5.6.4 Short-Term Effectiveness

The short-term effectiveness of a disposal alternative is based on the associated water quality impacts, potential for worker injury, risk of human and biota exposure to contaminants, and habitat loss during the implementation of the disposal action. Disposal options that involve more handling and unconfined transport of contaminated sediment (e.g., requiring clam-shell dredging, or utilizing barge or truck transport) would have a greater potential for human exposure to contaminants and worker injury. Short-term habitat loss and water quality impacts occurring during disposal would be greater for options involving deep-water placement and larger in-water disposal site footprints. The duration of these short-term impacts is determined by the disposal option's implementation period. Based on these characteristics, nearshore disposal has high short-term effectiveness, and CAD and upland disposal provide moderate short-term effectiveness. See **Table G-11** for scoring details.

Nearshore disposal has the greatest short-term effectiveness because it poses the least potential for human exposure and worker injury (based on the assumption that sediment is hydraulically dredged and transported in a pipeline to the proximate disposal location, thus requiring the least handling) and would result in moderate water quality impacts.

CAD disposal would pose significant environmental risks during construction; water quality impacts would result from resuspension of highly contaminated sediments falling through the water column. CAD Site 2 has better short-term effectiveness than CAD Site 1 because it is shallower (approximately half as deep), and less resuspension of contaminated sediments would occur upon placement. In order to maintain *in situ* sediment density for faster settling and less spreading upon placement, CAD disposal would require the use of a clamshell dredge for MSU dredging and a barge to transport the excavated sediment to the disposal site. These methods significantly increase the human health and environmental risks associated with any alternative involving dredging the MSU.

Upland disposal has a greater potential for risks to human health and worker safety as a result of the extensive handling that is required to remove, dry, load, transport and unload the contaminated sediment. Risks of contaminant release and exposure during upland sediment dewatering or during the transport of 12,000+ truckloads of sediment would be significant. Upland disposal also requires the longest implementation period. The upland site options are equally effective in the short-term.

5.6.5 Long-Term Effectiveness and Permanence

Long-term effectiveness is based on the reliability of containment, the degree of monitoring and maintenance necessary, and the adequacy of institutional controls required to protect the containment facility.

The greatest long-term effectiveness is provided by an upland disposal facility because it most reliably confines the contamination (i.e., via impermeable liners), and is easiest to monitor and maintain (i.e., the accessibility of an above ground surface facility would allow thorough inspections and monitoring to be performed). Because it is unlikely that this disposal site would be used in conjunction with other purposes and the surrounding land use is variable, strict controls would be required to protect the disposal site from disturbance. Long-term effectiveness is equal for the upland sites.

Nearshore disposal provides the next best long-term effectiveness. The nearshore facility provides less reliability because contaminants are not isolated with impermeable liners and there is a low potential for containment failure due to geotechnical (proximity of slope) and seismic stability issues. Although a nearshore disposal site would be more difficult to monitor and repair that an upland facility, the future use of the disposal site and adjacent land is more certain. The upland area of the nearshore facility could be designed to be compatible with adjacent land uses (i.e., incorporation into Port of Seattle's long-term intermodal yard development plans), providing good assurance that long-term monitoring and maintenance would be accomplished, and institutional controls to protect the facility would be enforced.

CAD disposal has the lowest degree of long-term effectiveness because containment failure due to contaminant diffusion or cap damage would be most difficult to monitor and repair, making long-term isolation difficult to ensure. The cap would be susceptible to damage from anchor drag and would require establishing a no-anchor zone in the vicinity of the site, and such institutional control would be difficult to implement and enforce. CAD Site 1 has better long-term effectiveness than CAD Site 2 because it is deeper and less subject to cap disturbances. See **Table G-12** for scoring details.

5.6.6 Implementability

Implementability concerns include the ease of construction, the reliability of the technologies involved, the ability to effectively monitor the containment, the availability of disposal sites, the disposal option's impact to fisheries, and the time necessary to complete the disposal facility.

Upland disposal is the easiest to implement because upland confinement is well documented as a reliable technology, monitoring an accessible upland facility is most effective, and the disposal option does not impact fisheries. There are, however, significant construction difficulties associated with the implementation of upland disposal. Construction of two dewatering cells, approximately 2 to 3 acres in size, would be required to dry the sediment prior to transport and disposal. Presently, a dewatering location has not been identified. In addition, the implementation period for upland disposal is the longest. Industrial upland sites identified for this project have the same ease of implementability.

Nearshore disposal requires a moderate implementation effort. Difficulty is anticipated in obtaining approval to fill the nearshore area, which falls within a tribal fishing area and would remove some shallow subtidal salmonid habitat; loss of habitat has potentially significant impacts to a proposed threatened species, the Puget Sound Chinook salmon.

CAD disposal is the most difficult to implement because placement of highly contaminated sediment in deep water by clamshell is difficult and the reliability of this application of the technology is not high. In addition, monitoring a deep-water cap is less effective than a more accessible upland or nearshore facility. CAD Site 2 is easier to implement than CAD Site 1 because it is easier to accurately place sediment and effectively monitor a cap at shallower depths.

The various issues affecting implementation of a disposal option results in similar scores for all options. **Table G-13** presents the scoring details.

Sites have been identified for all disposal options. There is currently not enough information, however, to distinguish between the administrative difficulties associated with siting such facilities at these locations.

5.6.7 Cost

The unit and total costs associated with the disposal options are displayed in **Table 5-5**. These costs include the incremental costs, such as dredge standby time and trucking costs, necessary to accommodate the disposal type. CAD disposal has the lowest cost, the cost for nearshore disposal is moderate, and the upland disposal cost is highest (see Table G-14 for ranking). The nearshore and CAD disposal costs, however, do not include the compensation costs associated with disposal on DNR land. The inclusion of these costs may significantly change the relative ranking (with respect to cost) of disposal alternatives.

5.7 SUMMARY

Tables 5-6 and 5-7 provide the results of the numerical evaluation for remedial alternatives and disposal options, respectively. As shown, Alternative 3b—Capping to CSLs has the highest ranking, followed closely by Alternative 4b—Fill Removal and Capping to CSLs. Of the disposal options, nearshore and upland disposal are tied with the highest ranking.

SECTION 6

PREFERRED ALTERNATIVE

6.1 PREFERRED ALTERNATIVE

The preferred alternative for the remediation of PSR sediment is Alternative 3b—Capping to CSLs. Several modifications have been applied to this alternative in order to address nearshore habitat quality for aquatic resources, including outmigrating juvenile salmonids. Specific modifications include:

- Extending the shoreline cap to include the entire property boundary.
- Expanding the cap in shallow (less than -30 feet MLLW) nearshore areas to remediate sediments containing PCBs greater than the SQS.

Figure 6-1 presents the modified configuration for the preferred alternative. The remaining elements are as described in **Section 4.2.3.2**. Use of the CSL as the primary cleanup level is discussed in **Appendix J.**

The changes in volumes of capping material that may be required and the additional costs are not provided in this draft FS; this information will be included in the revised document, following receipt of public and agency comments. It is not anticipated that the modifications to Alternative 3b will change its ranking relative to other alternatives.

This modified alternative has the best compliance with the seven CERCLA evaluation criteria and comes closest to meeting the project performance objectives for the entire site. There are, however, implementability and longevity concerns associated with this remedial alternative (see **Section 6.4)** that will need to be addressed as part of remedial design.

6.2 COMPLIANCE WITH CERCLA CRITERIA

Modified Alternative 3b—Capping to CSLs would consist of placing a 3-foot cap over the area of the MSU that exceeds CSLs for PAHs and exceeds the SQS for PCBs. A high degree of protectiveness is provided because the capping material is characterized by background contaminant concentrations (lower than SQS), and the residual human health risks associated with this remedy would be below the NCP federal risk objectives. The remedial action would meet ARARs.

This alternative would provide the greatest short-term effectiveness. Capping to CSLs involves dredging a relatively small area (limited to CMS vicinity), resulting in a significantly lower potential for adverse water quality impacts, human exposure to contaminants, and worker injury during implementation. Because the cleanup area is relatively small (CSL exceedance area), the relative degree of short-term habitat loss would be lower. The minimal short-term impacts associated with capping would persist during the capping phases for the implementation period of 3.7 years unless another source of material is used. This alternative does not require disposal, further reducing the total duration of implementation relative to alternatives that do require the construction of a disposal facility.

With the appropriate monitoring and maintenance, capping provides long-term isolation of contaminants and provides a high quality habitat for marine organisms. Implementation of capping is technically feasible and has been previously demonstrated by successful confinement of contaminated sediment in aquatic environments elsewhere in Puget Sound. Implementation and long-term effectiveness concerns associated with capping are addressed in **Section 6.4**.

The total cost for modified Alternative 3b—Capping to CSLs is estimated to be $7,600,000 (see **Appendix F**), and is the lowest cost of all remedial alternatives. However, this cost does not include the compensation costs associated with the disposing of contaminated sediment on land owned by the State of Washington. The inclusion of such costs, when determined, may result in cost comparison re-ranking.

6.3 COMPLIANCE WITH PERFORMANCE CRITERIA

This alternative has minimal impacts to fisheries. Although, capping activities could result in the interruption of tribal fishing activities in the vicinity of the MSU during the periodic capping phases, this alternative would have no long-term adverse effect on fisheries (e.g., no loss of fishery area).

This alternative would have minimal impacts to water-dependent industries by being completed expeditiously, reducing the period that commercial vessels have to navigate around barges. Short-term impacts to CMS operations are anticipated during dredge and cap efforts in the vicinity of their terminal for a duration of up to 2 weeks. Long-term anchoring restrictions in the capped areas of the MSU would be the most significant impact to water-dependent uses; however, only 47 acres would be removed from the entire Elliott bay anchorage area.

The implementation period for this alternative (3.7 years) slightly exceeds three years. The short-term impacts associated with implementation, however, are minimal and they do not persist through the entire period (i.e., intermittent capping phases). Furthermore, a disposal option is not required, reducing the total duration relative to alternatives which require the construction of a disposal facility.

Capping is expected to have minimal short-term and no long-term adverse impacts to endangered species. This alternative provides high quality habitat by capping with material characterized by concentrations lower than SQS criteria. In addition, this alternative does not require the construction of a disposal facility, which could involve the loss of critical salmon habitat.

To achieve at least 30 years of contaminant isolation, the cap would require intensive long-term inspection, monitoring and maintenance. Such management of an in-place cap would be a fundamental component in this alternative to ensure the cap met the design life.

This alternative reduces human health risks to 6.6E-05, below the NCP federal risk objective of 1 in 10,000.

This alternative does not affect the geotechnical stability of the MSU shoreline because the shoreline area is capped.

The water quality impacts associated with this alternative are relatively very low. Dredging is limited to a relatively small area (CMS vicinity), resulting in a significantly lower potential for adverse water quality impacts.

6.4 PRE-DESIGN INVESTIGATION TO ASSESS IMPLEMENTABILITY AND RELIABILITY OF CAPPING

Capping is an implementable and reliable method of contaminant isolation, given appropriate site conditions. Site features at the MSU pose uncertainties about the static stability of a cap and the ability to place capping material without recontamination of the cap surface. A pre-design investigation may be necessary to confirm the implementability and longevity of a cap on the MSU. The following is a brief description of the elements of a pilot test cap.

This remedial alternative assumes placement of capping material via barge washoff. Such placement on the fill areas should minimize disturbance and resuspension of the soft and highly-contaminated sediment. However, the potential for resuspension of contaminated sediment is dependent upon a number of parameters such as sediment water content of the surface layer. The potential for cap recontamination is also dependent on the chemical concentrations in the surface sediments. It may be prudent to perform a pilot-scale cap test in the fill area to ensure that the chosen placement method produces a viable cap. Cores should be analyzed to investigate the degree of mixing of contaminated sediment with the cap upon placement, and to ensure that the surface of the cap does not exceed SMS criteria. The pilot test may show that a more controlled placement method is required to minimize disturbance and protect the cap quality. Costs do not reflect highly refined cap placement.

The long-term effectiveness of contaminant isolation by a cap at the MSU is uncertain due to static stability issues. Approximately 35 percent of the MSU CSL exceedance area has slopes between 18 and 21 percent. In addition, USGS sub-bottom profiling data suggests that there may be mounds of fill material in a number of locations on the bottom. A cap placed on an area with high slope (greater than 20 percent) has a potential for slump and containment failure. To determine if the cap would provide long-term containment, the site bathymetry should be refined to further investigate borderline slope and to determine if steeply-sloped fill mounds are present.

If these mounds are present, they may require spot removal prior to capping, or additional placement of material.

SECTION 7

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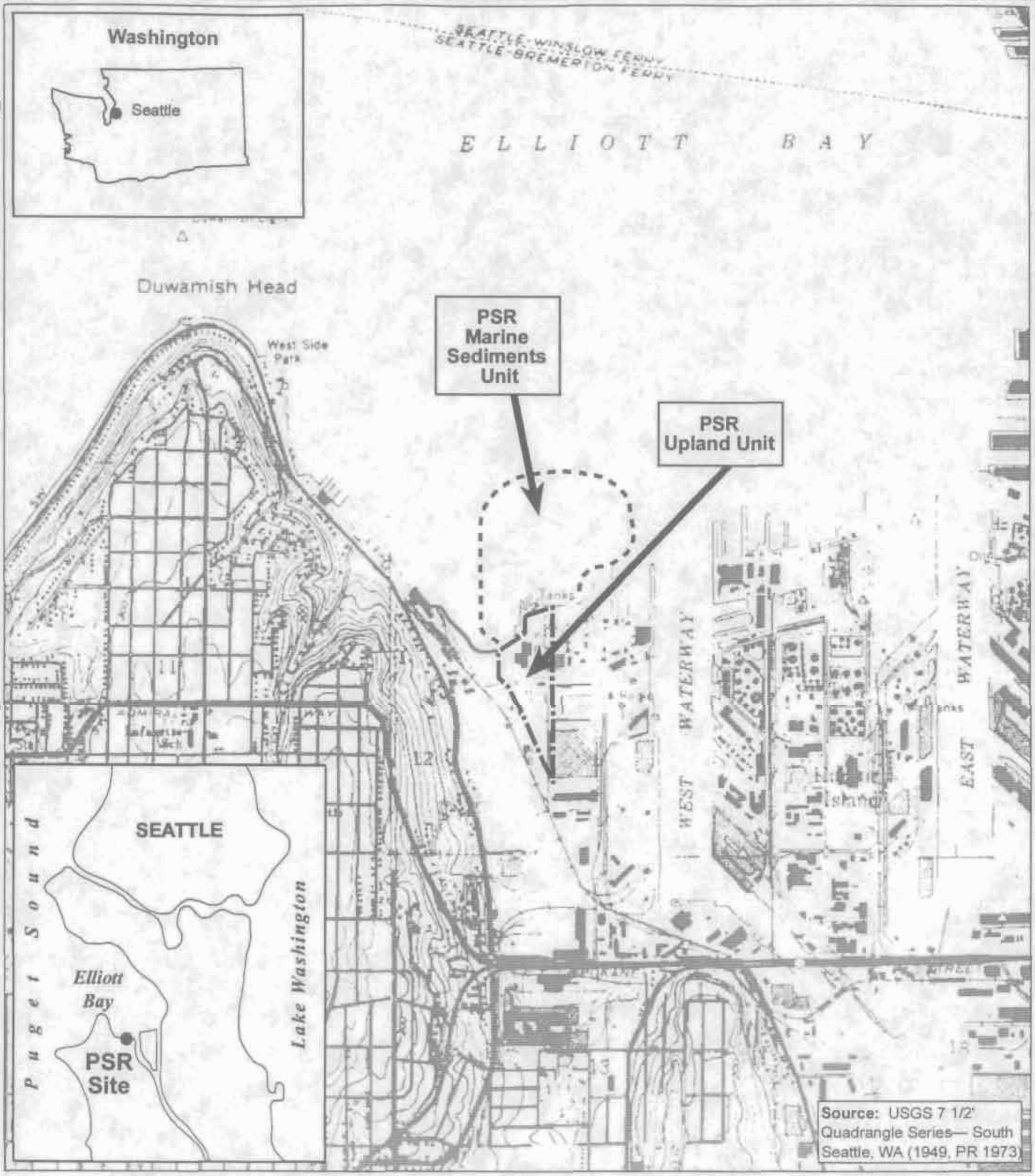
FIGURES



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Scale in Feet

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MANAGERS DESIGNERS/CONSULTANTS

PSR Upland and
Marine Sediments Unit
Location Map

FIGURE
1-1

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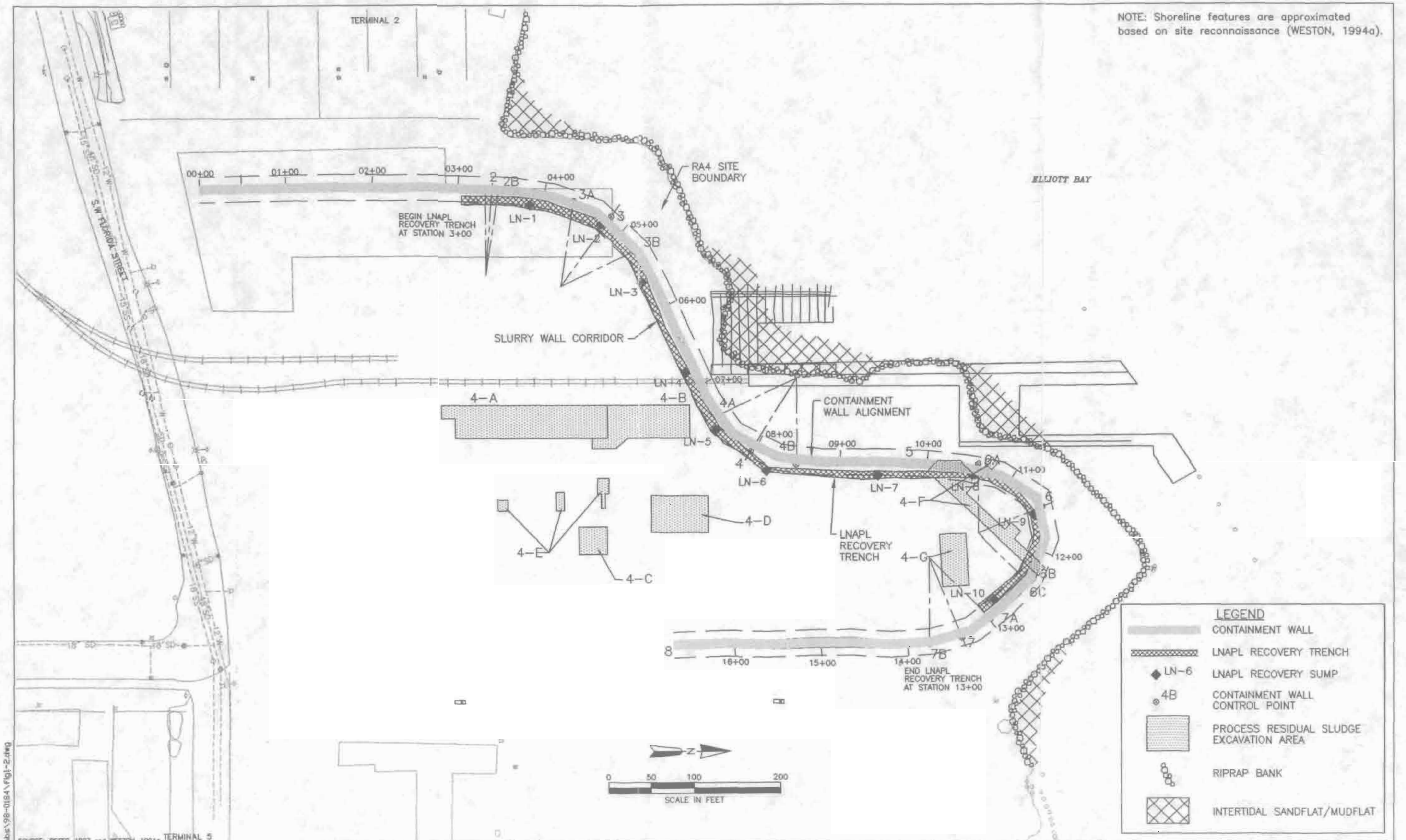
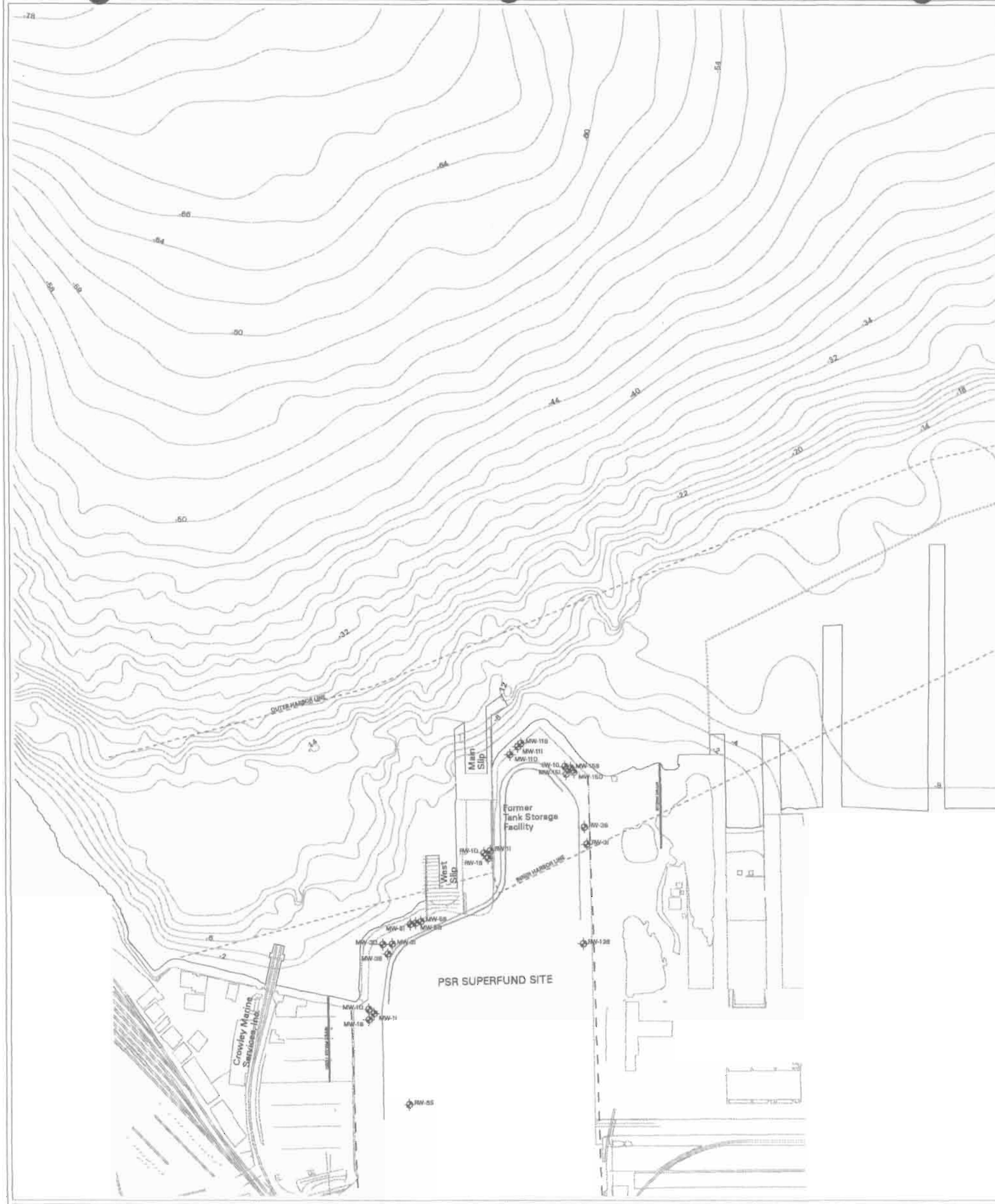


PSR Superfund Site
Locations of Process Residual Sludge Excavation and Shoreline Features

FIGURE 1-2



BASEMAP EXPLANATION

- Upland Feature
- Shoreline
- Upland Property Boundary
- Bathymetry
- Drain
- Harbor Line
- Slurry Wall
- LNAPL Recovery Trench
- Lockheed cleanup action plan boundary

SYMBOL EXPLANATION

- Upland groundwater monitoring well
- Capped Area (See also Note 4)

GN MN
21°

SCALE 1:3100
50 0 50 100 150 200
Feet

PSR Site

NOTES

1) Vertical datum is: Meters Mean Lower Low Water (MLLW).
2) Bathymetric data source: NOAA, 1970 & 1995.
3) Locations of slurry wall, LNAPL trench, and monitoring wells approx. (RETEC, 1996a, 1996b).
4) Areas not capped with asphalt will be covered with clean fill and landscaping.
5) Intertidal pocket beaches exist at the head of each of the slips (West and Main).

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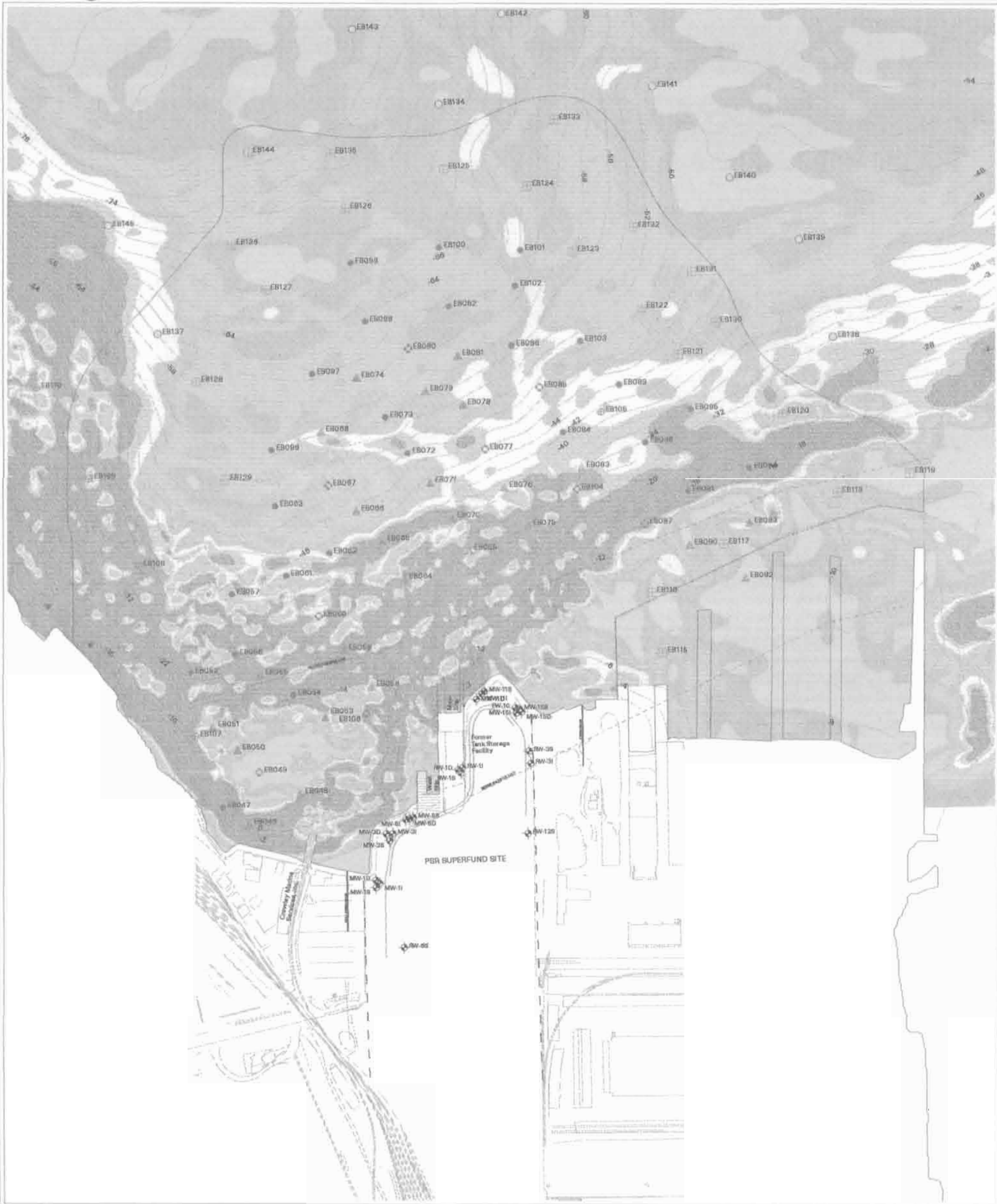
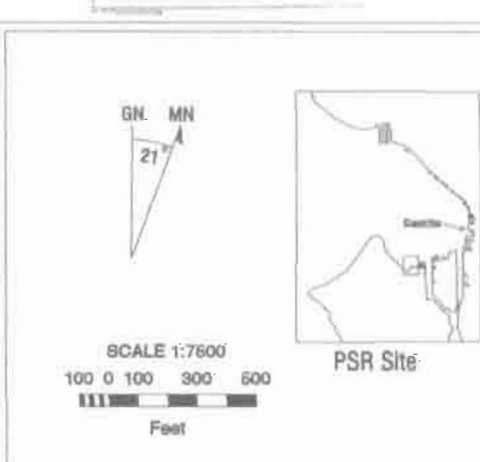
PSR Upland and Marine Sediments Unit Site Features

Figure 1-3



SYMBOL EXPLANATION

- 0 - 3 Percent slope
- 3 - 6 Percent slope
- 6 - 9 Percent slope
- 9 - 12 Percent slope
- 12 - 15 Percent slope
- 15 - 18 Percent slope
- 18 - 21 Percent slope
- > 21 Percent slope



NOTES

1) See Figure 1-3 for site feature notes and global symbols.

2) Bathymetric data source: NOAA, 1970 and 1995.

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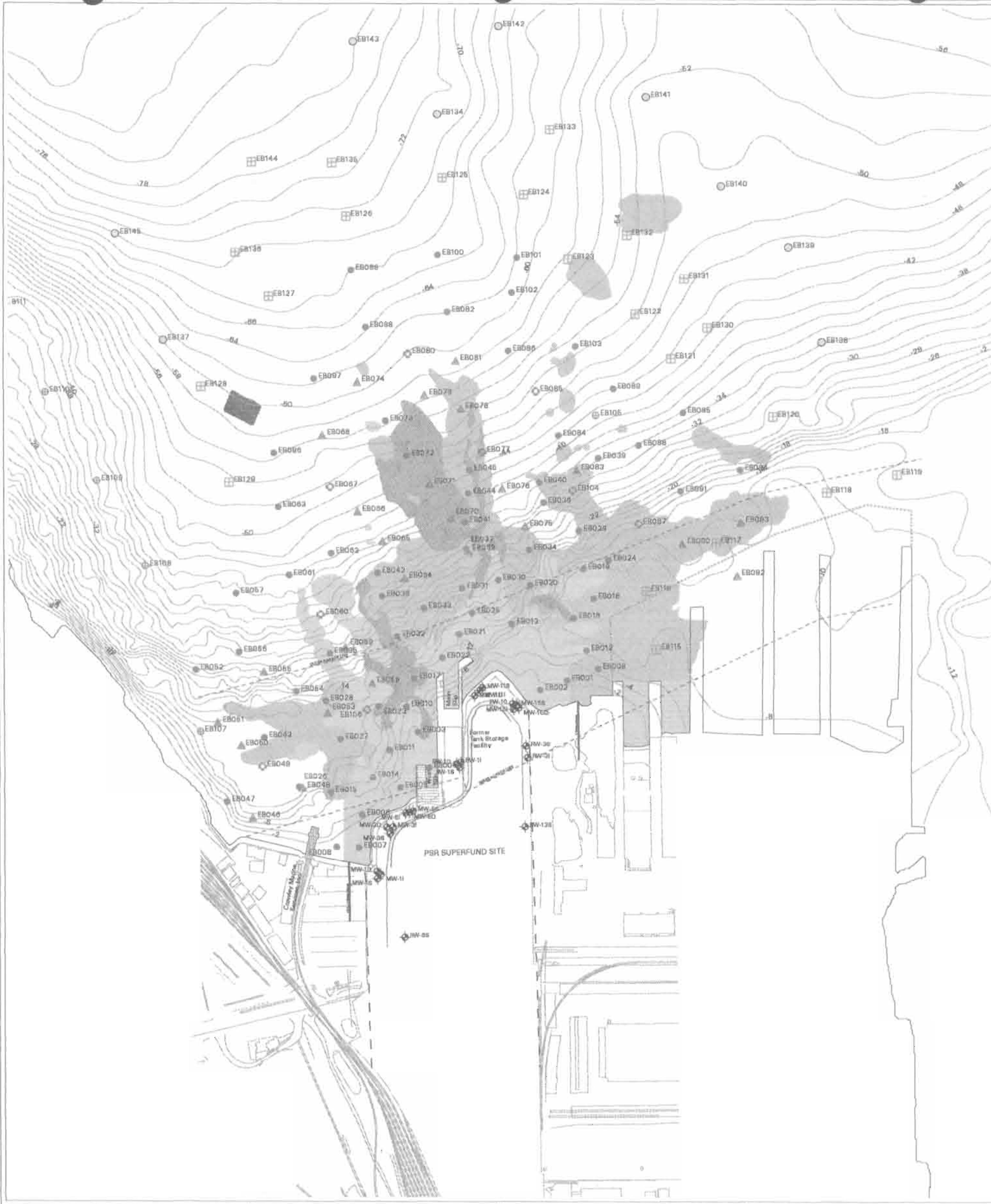
PSR Marine Sediments Unit
Bottom Slopes

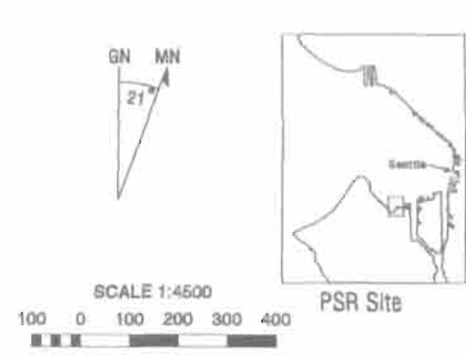
FIGURE

1-4



SYMBOL EXPLANATION

- High acoustic backscatter (probable fill)
- Medium acoustic backscatter (potential fill)
- Low acoustic backscatter (possible fill)
- Sunken vessel
- Unknown
- Native sediment



NOTES

1) See Figure 1-3 for site feature notes and global symbols.
2) Backscatter data source: U.S.G.S., 1996

WESTON

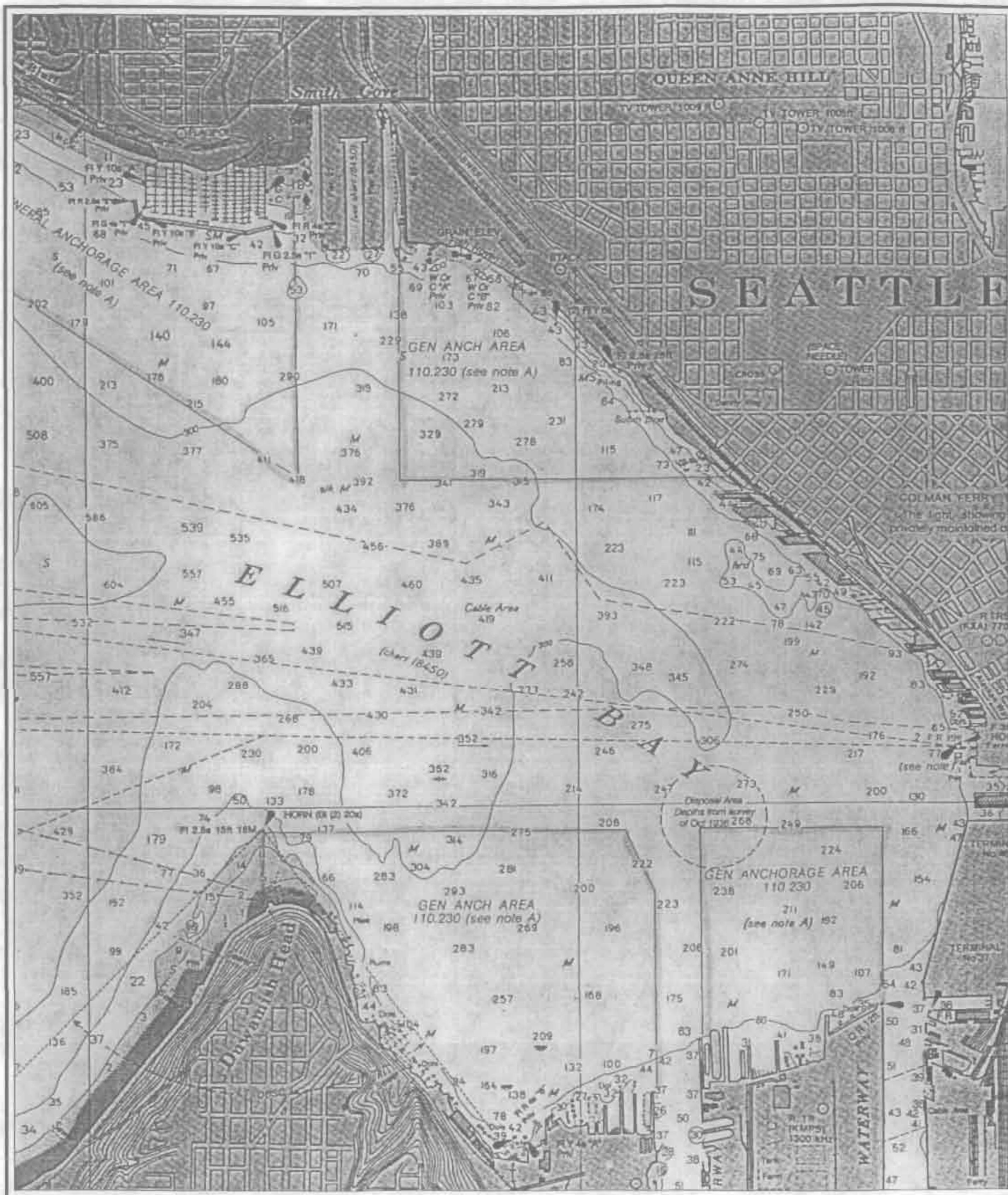
DATE: October 14, 1998 8:35 PM
JOB NUMBER: 98-0184
VIEW FILE: backscat.view

CHECKED BY: ____________

APPROVED BY: ____________

PSR Marine Sediments Unit Backscatter Intensity Interpretation of Side Scan Sonar Data

Figure 1-5



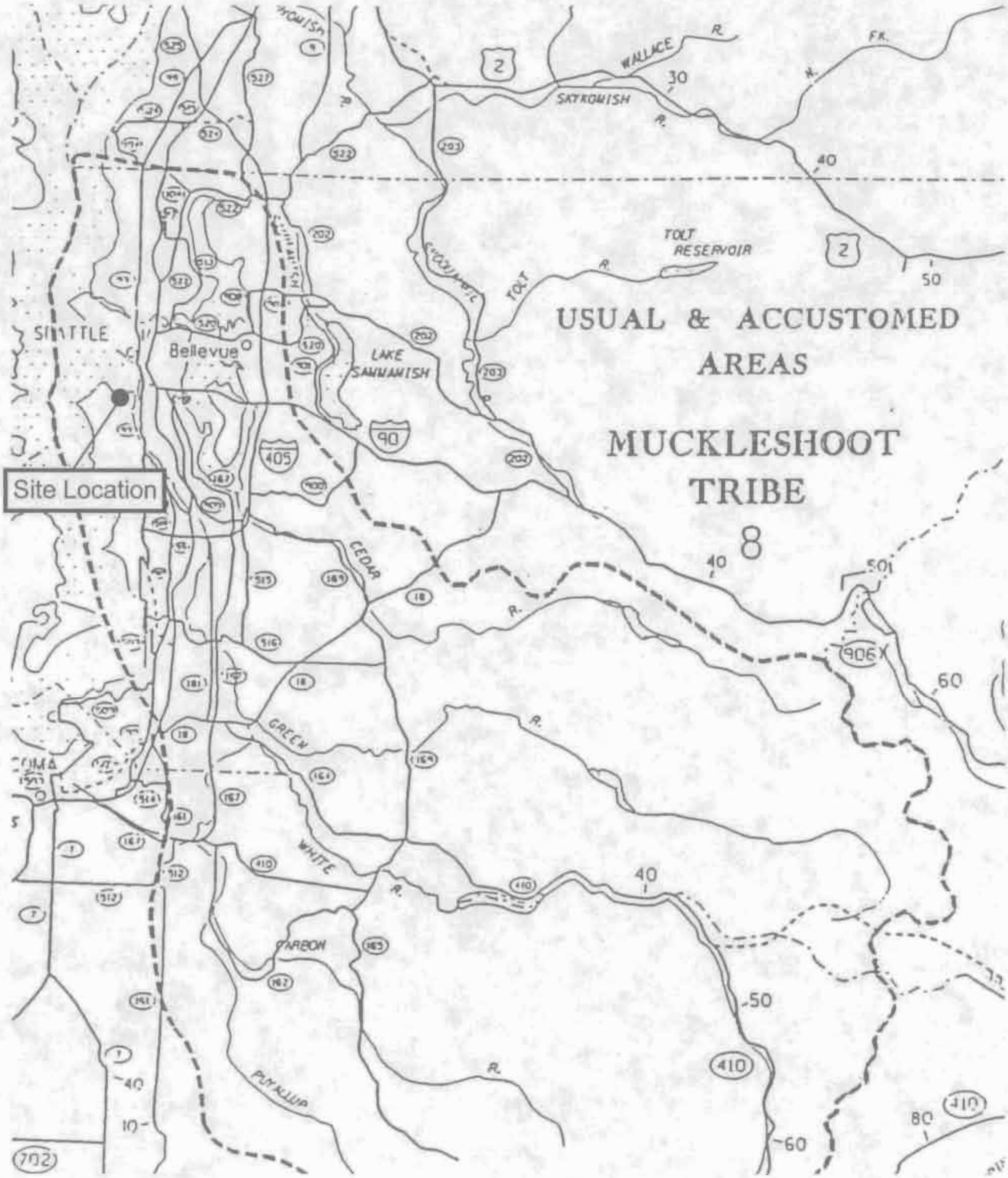
Locations of General Anchorage Areas

FIGURE

1-6

WESTON
MANAGERS DESIGNERS/CONSULTANTS

98-0515 Fig1-6.fh8



Fishing Area

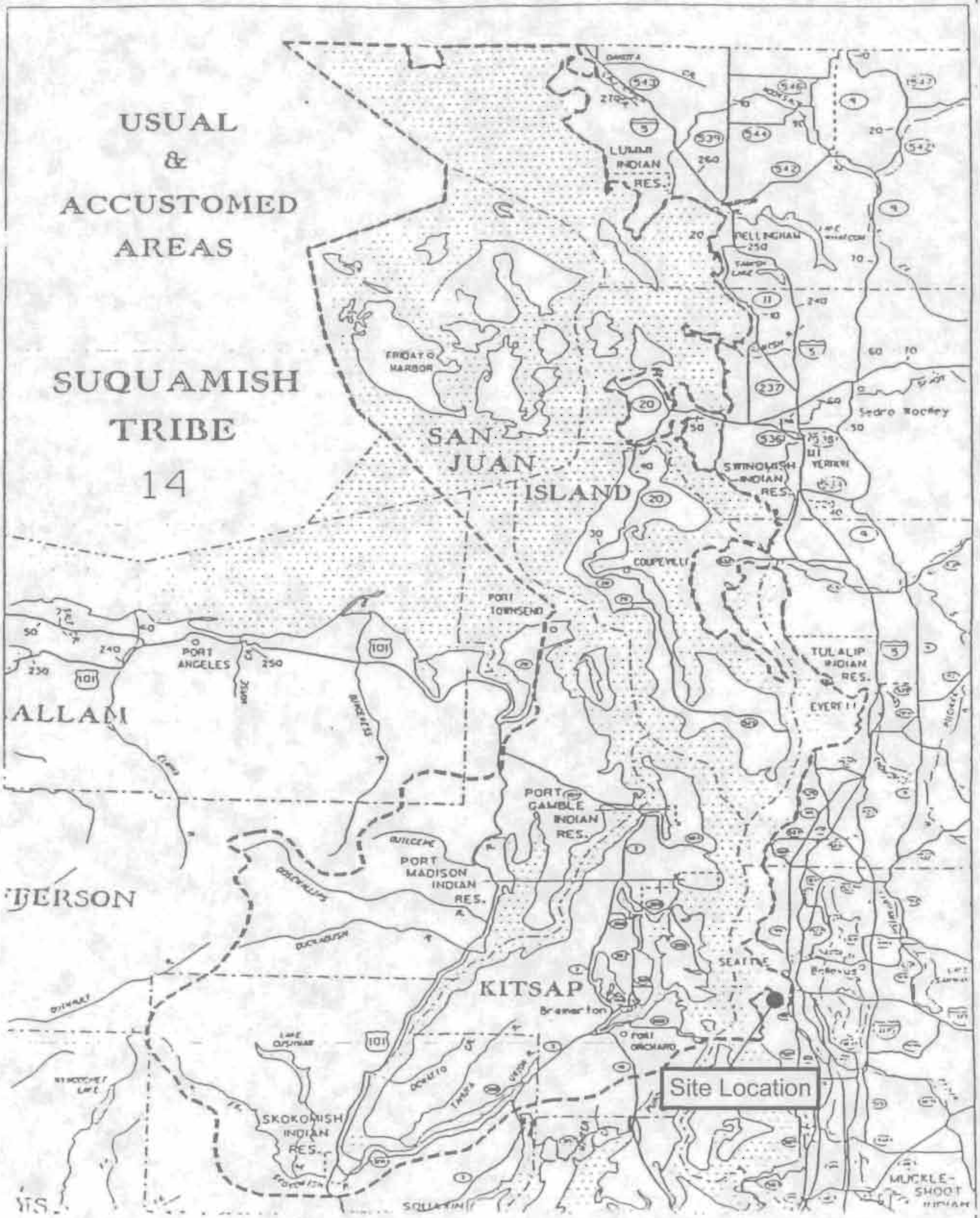
Muckleshoot Tribe Usual and Accustomed Fishing Area

WESTON

FIGURE

1-7

98-0515 Fig1-7.fh8



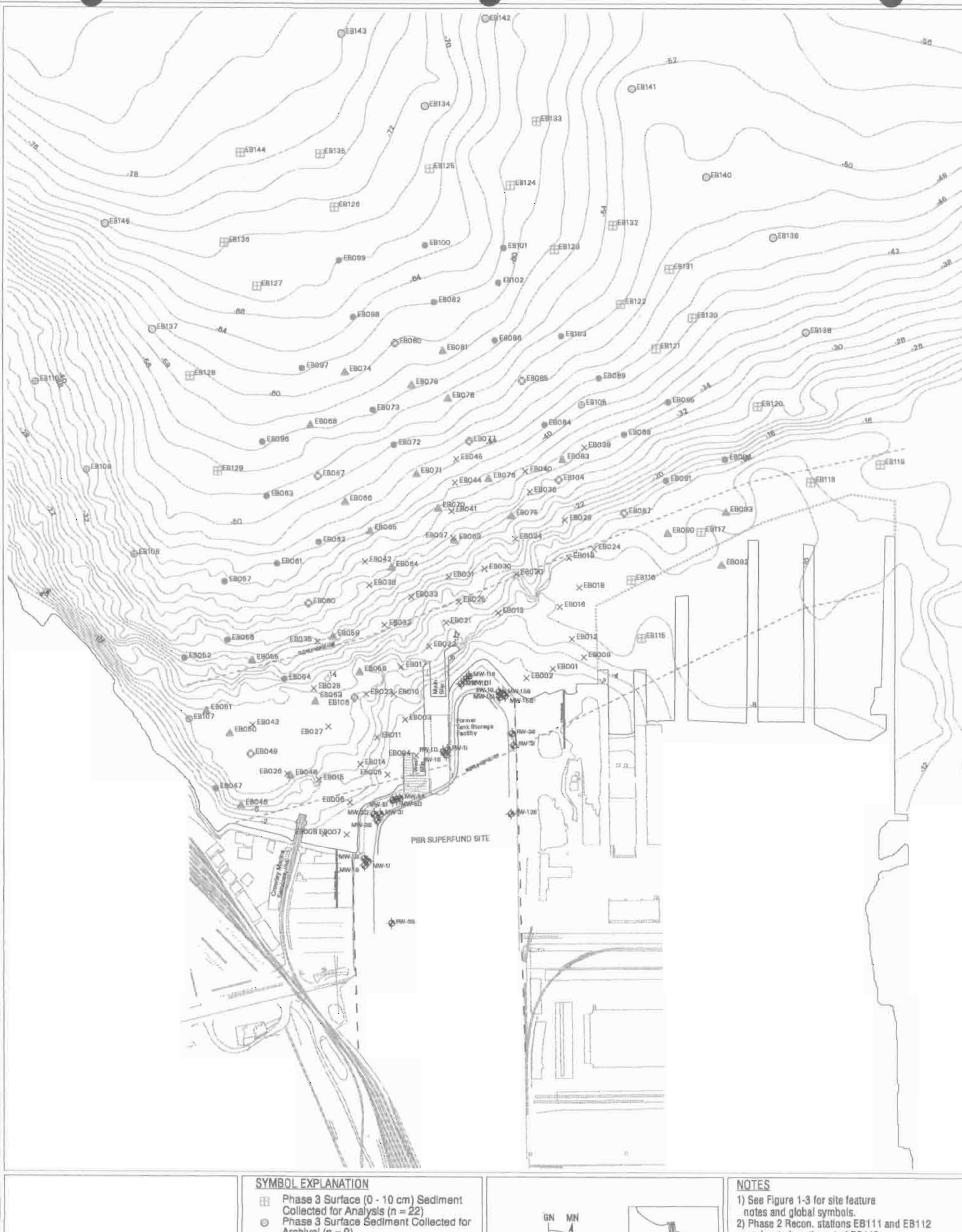
Suquamish Tribe Usual and Accustomed Fishing Area

FIGURE

1-8

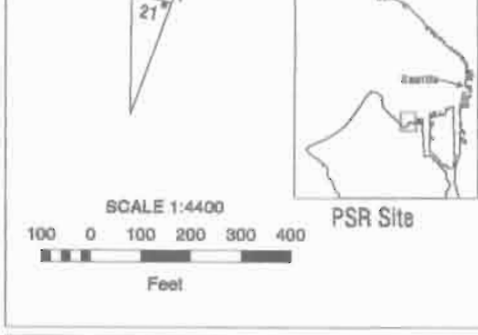
WESTON
MANAGERS DESIGNERS/CONSULTANTS

98-0515 Fig1-8.fh8



SYMBOL EXPLANATION

- Phase 3 Surface (0 - 10 cm) Sediment Collected for Analysis (n = 22)
- Phase 3 Surface Sediment Collected for Archival (n = 9)
- Phase 2 Surface (0 to 10 cm) Sediment Station - Chemistry Only (n = 7)
- Phase 2 Sediment Triad Station - Bioassays, Benthos, Surface (0 to 10 cm) Chemistry (n = 9)
- Phase 2 Surface (0 to 10 cm) Sediment Station - Chemistry and/or Field Immunoassays (n = 26)
- Phase 2 Surface (0 to 10 cm) Sediment Station - Field Immunoassay Only (n = 25)
- × Phase 1 Surface (0 to 10 cm) Sediment Sample - Chemistry Only (n = 45)



NOTES

1) See Figure 1-3 for site feature notes and global symbols.
2) Phase 2 Recon. stations EB111 and EB112 are located northwest of EB110.
3) Stations EB115 and EB092 located within the Lockheed cleanup action plan boundary.

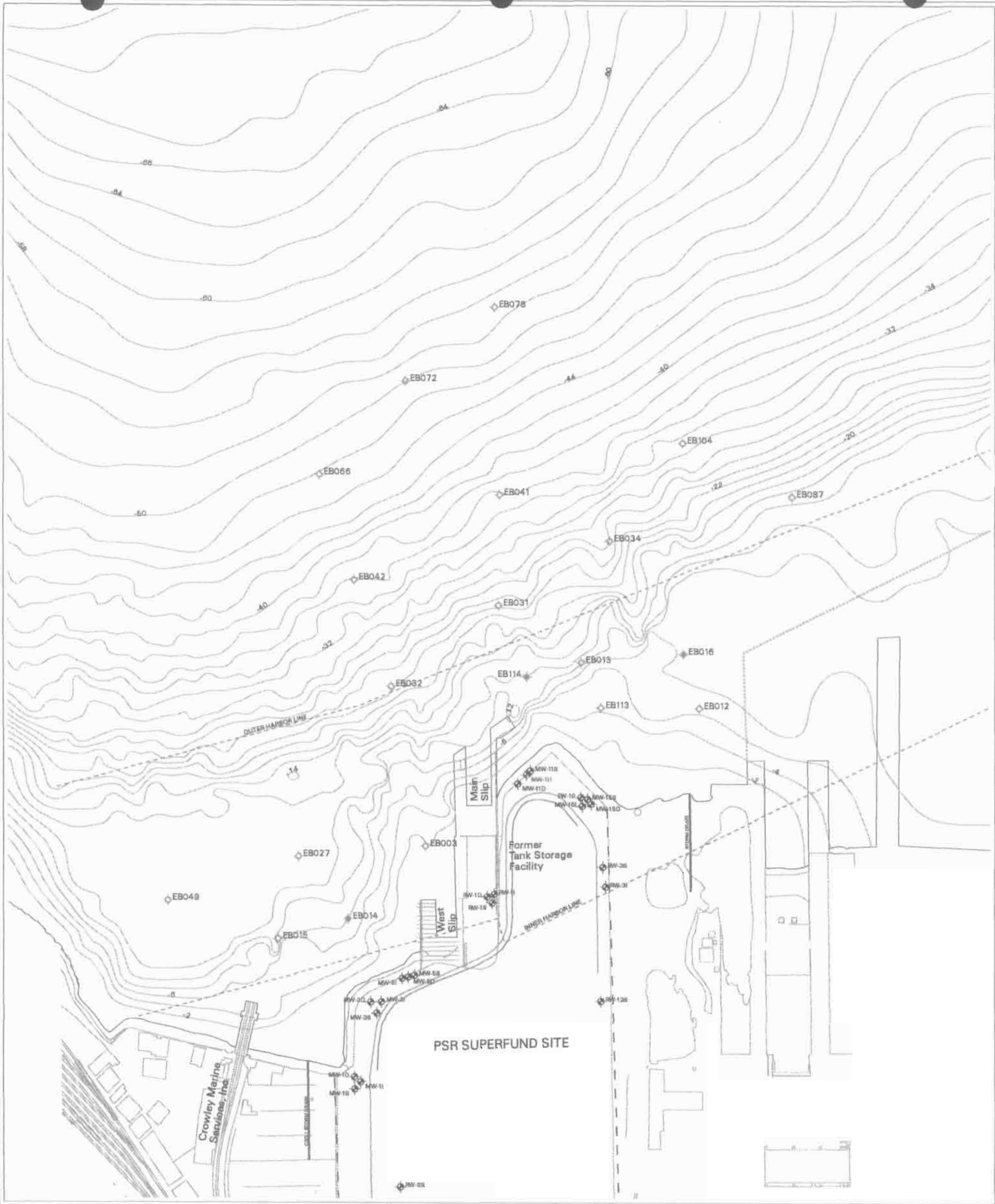
DATE: October 26, 1998 11:16 AM
JOB NUMBER: 98-0184
VIEW FILE: allstns.view

CHECKED BY: ____________

APPROVED BY: ____________

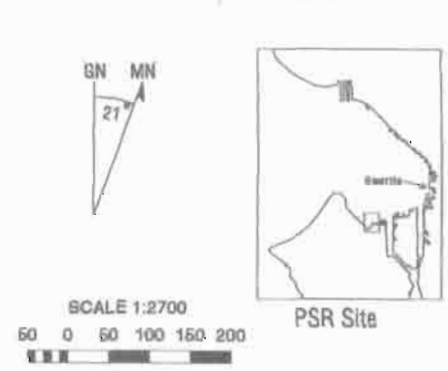
PSR Marine Sediments Unit Phase 1, 2, and 3 Surface Sediment Chemical and Biological Sampling Locations

Figure 2-1



SYMBOL EXPLANATION

- Shallow (0 to 20 ft) Subsurface Sediment Core (n = 17)
- Deep (0 to 96 ft) Subsurface Sediment Core (n = 3)



NOTES

1) See Figure 1-3 for site feature notes and global symbols.
2) Refusal encountered at four stations as follows:
EB012: 12 ft below mudline
EB042: 8 ft below mudline
EB072: 19 ft below mudline
EB113: 7 ft below mudline

WESTON

DATE: October 26, 1998 11:17 AM
JOB NUMBER: 98-0184
VIEW FILE: subsurface.view
CHECKED BY: ____________
APPROVED BY: ____________

PSR Marine Sediments Unit Phase 2 Subsurface Sediment Sampling Locations

Figure 2-2

BASEMAP EXPLANATION

Potential Fill Thickness in Meters

Extrapolated Fill Boundary

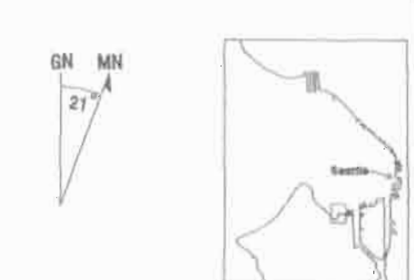
SYMBOL EXPLANATION

Below TOCN SQS or LAET

Above TOCN SQS or LAET

Above TOCN CSL or 2LAET

Asphalt Cap



SCALE 1:2900

50 0 50 100 150 200

Feet

NOTES

See Figure 1-1 for site features notes.

1) Exceedances based on individual or group totals for PAHs.

2) Fill contours from USGS sub-bottom profiling data (1996).

WESTON

DATE: March 09, 1998 1:44 PM
JOB NUMBER: 98-0515
VIEW FILE: Fig2-3.ai7

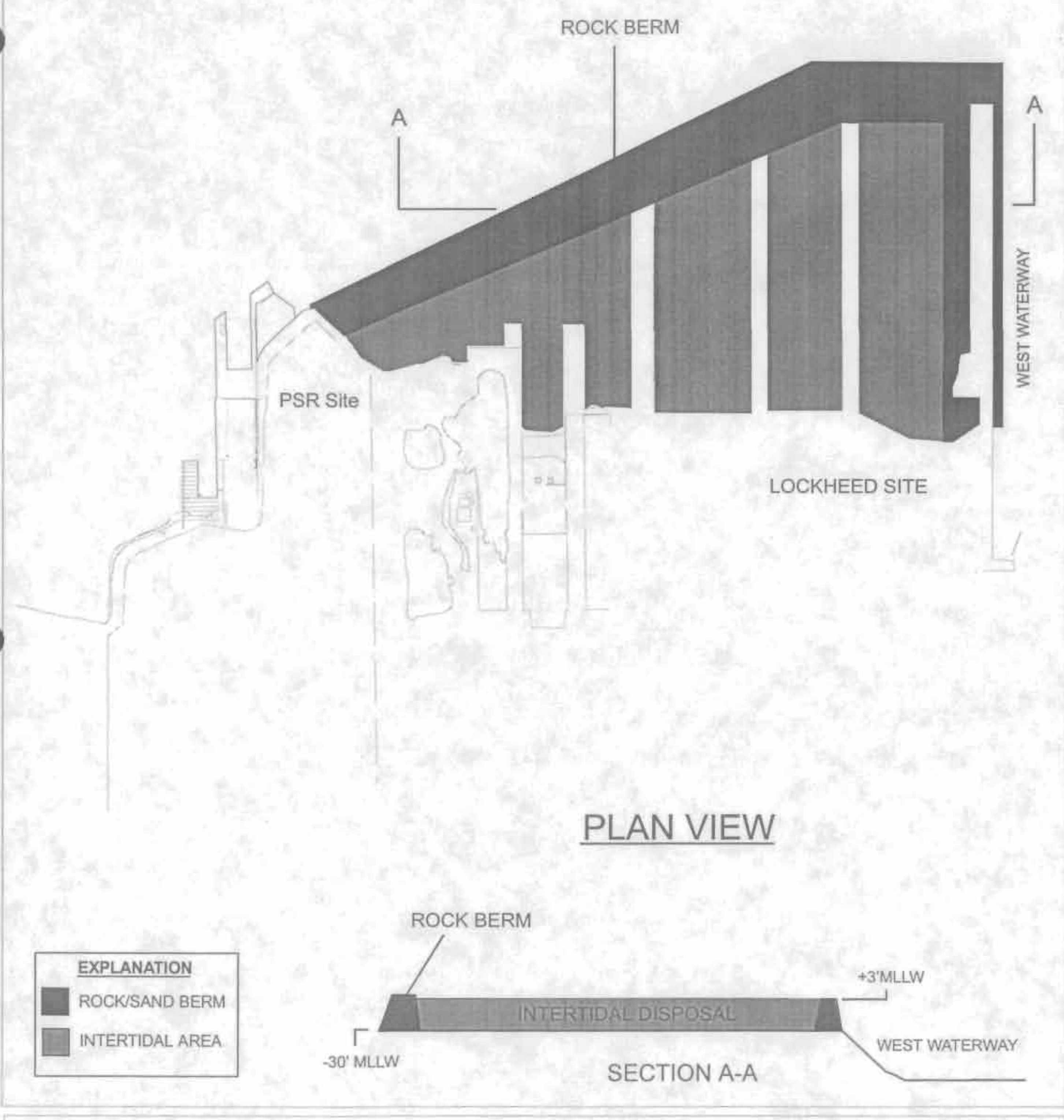
CHECKED BY: ____________

APPROVED BY: ____________

PSR Marine Sediments Unit Surface Sediment PAH Exceedance[1] Areas and Fill Contours[2]

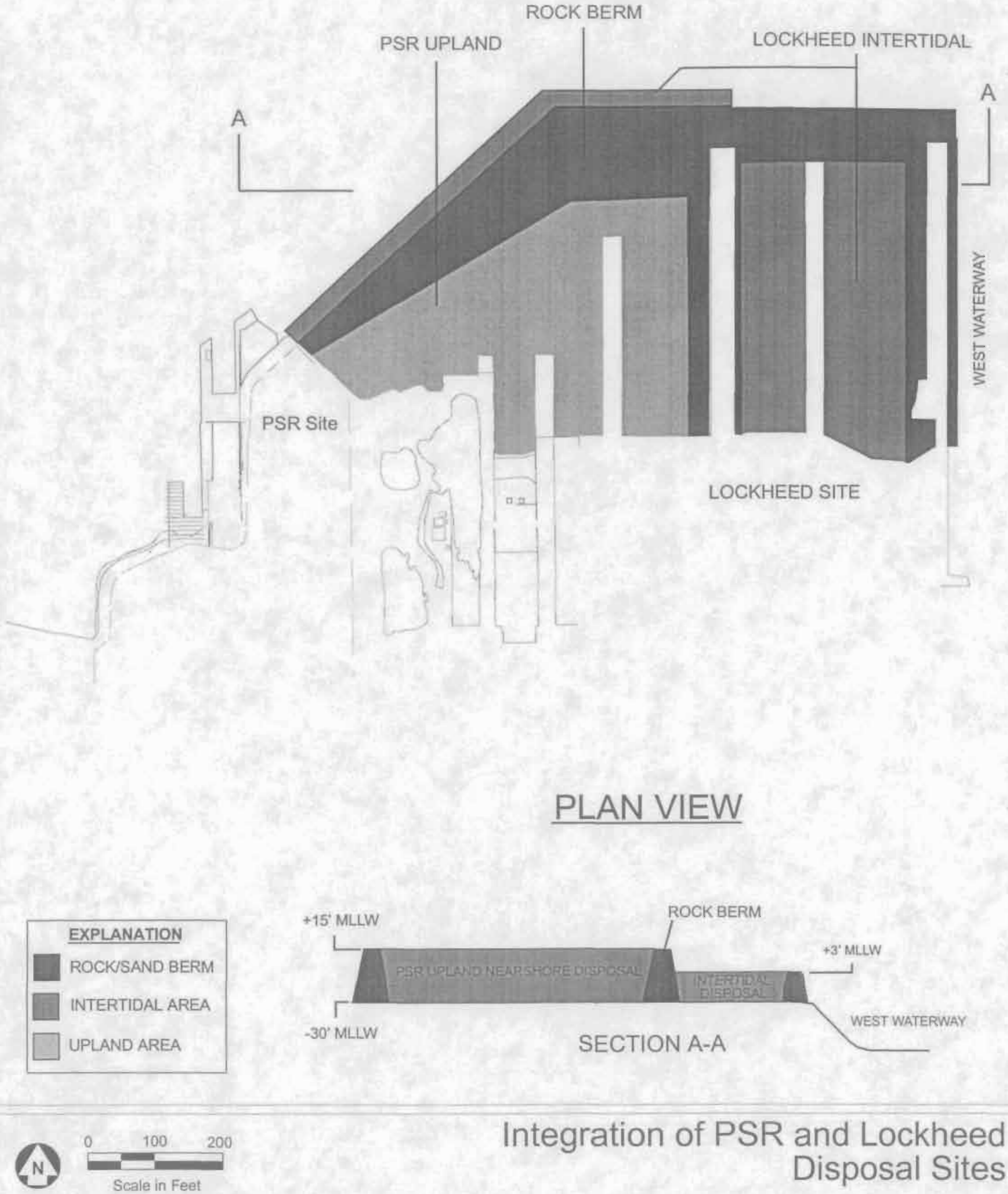
FIGURE

2-3



Lockheed Cleanup Action Plan
Disposal Configuration

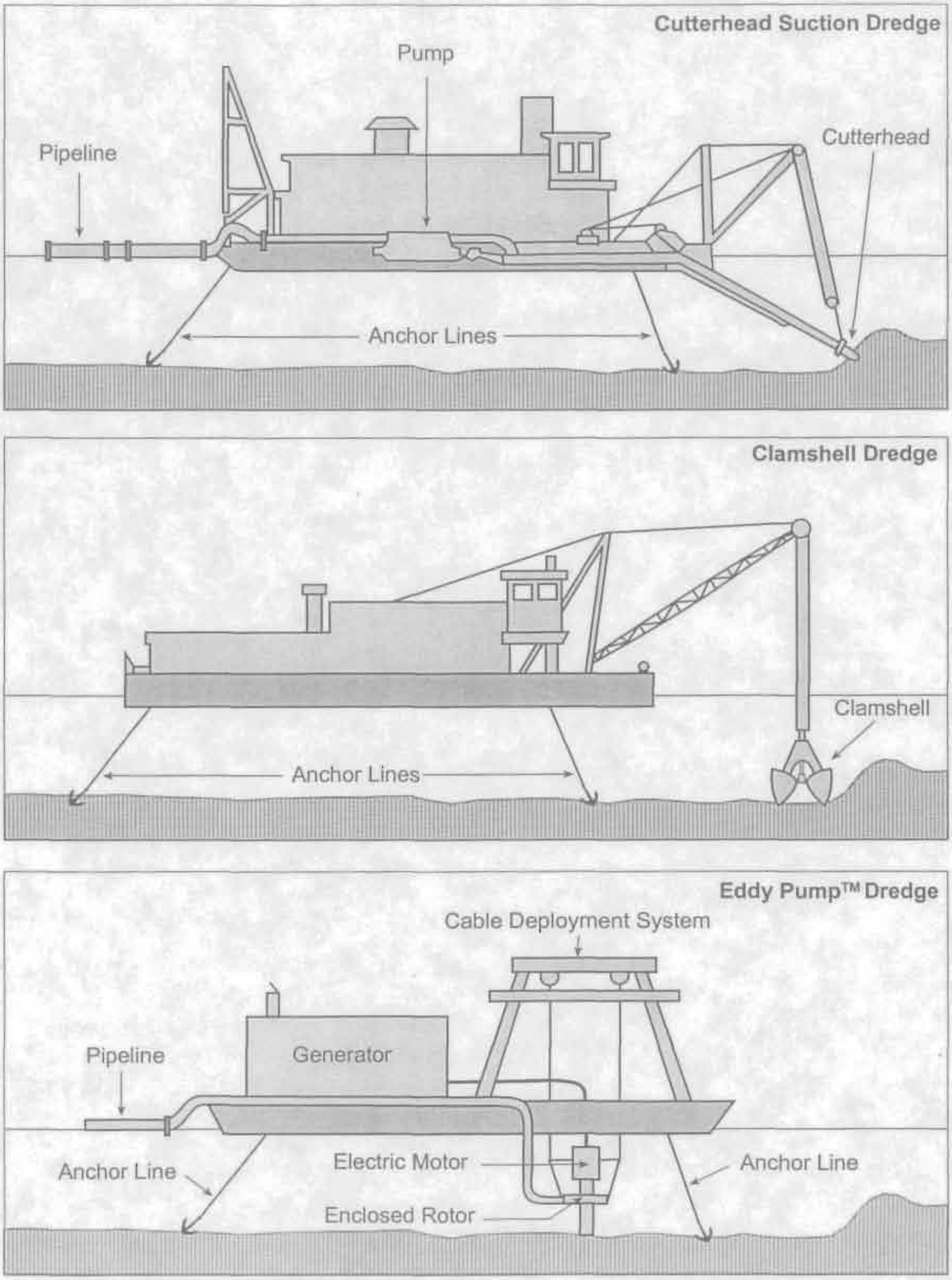
FIGURE
3-1



Integration of PSR and Lockheed Disposal Sites

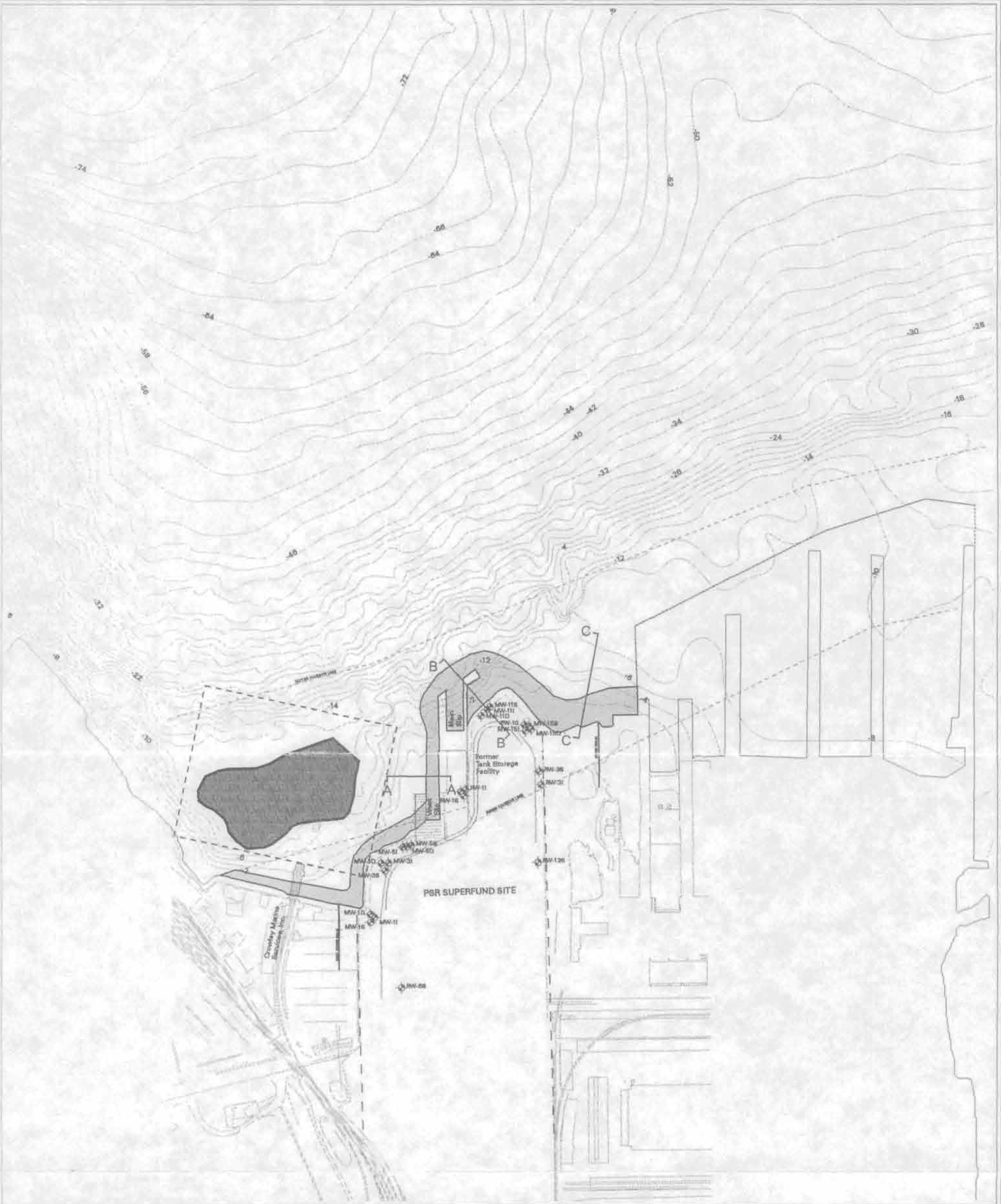
FIGURE
3-2

98-0515 Fig3-2.fh8



PSR Marine Sediments Unit
Potential Dredging Equipment

FIGURE
4-1



EXPLANATION

No dredging allowed due to slope stability. Cleanup goals acheived by capping.

Intermediate groundwater discharge zone associated with west-central shoreline wells containing DNAPL. (See Section 3 of the RI)

Crowley Marine barge moorage area.

GN MN

21°

SCALE 1:2900

50 0 50 100 150 200

Feet

PSR Site

NOTES

See Figure 1-3 for site features notes.

WESTON

DATE: March 09, 1998 1:44 PM
JOB NUMBER: 98-0582
VIEW FILE: Fig4-2.fh8

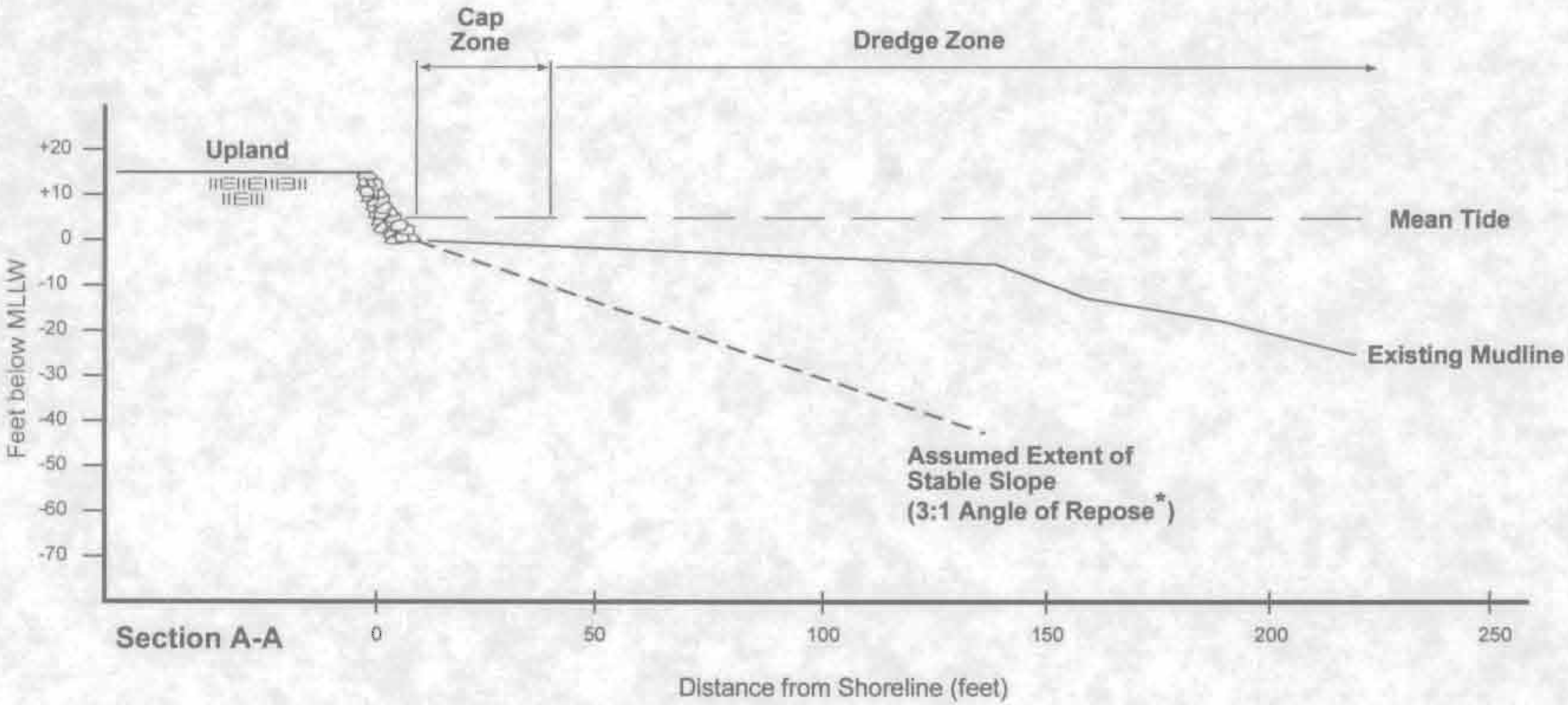
CHECKED BY: ____________

APPROVED BY: ____________

PSR Marine Sediments Unit Project Specific Requirements

FIGURE

4-2



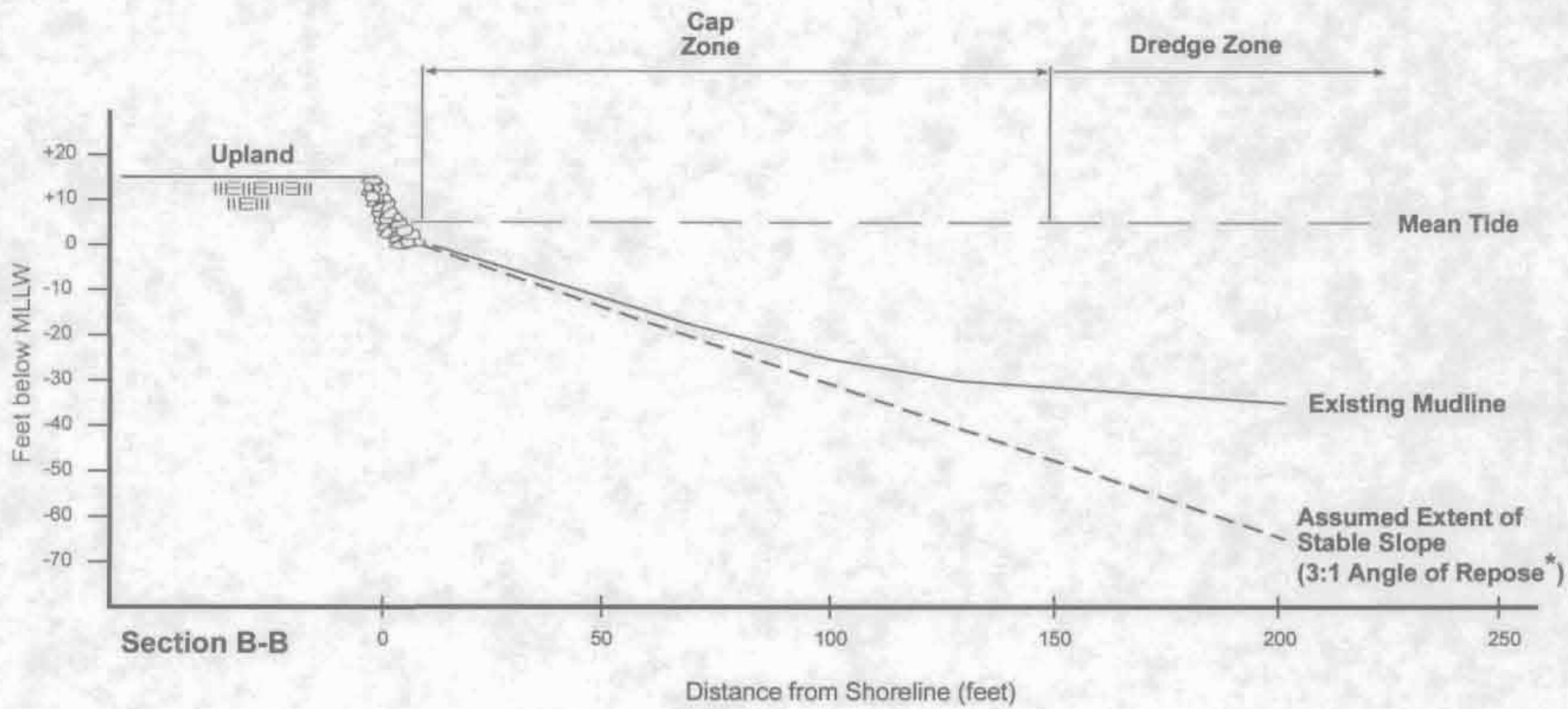
Notes: See Figure 4-2 for cross-section locations.
* Corp. of Engineers - Technical Report D-77-9

PSR Marine Sediments Unit
Cross-Section A-A

FIGURE
4-3

WESTON

98-0515 Fig4-3.fh8



Notes: See Figure 4-2 for cross-section locations.

* Corp. of Engineers - Technical Report D-77-9

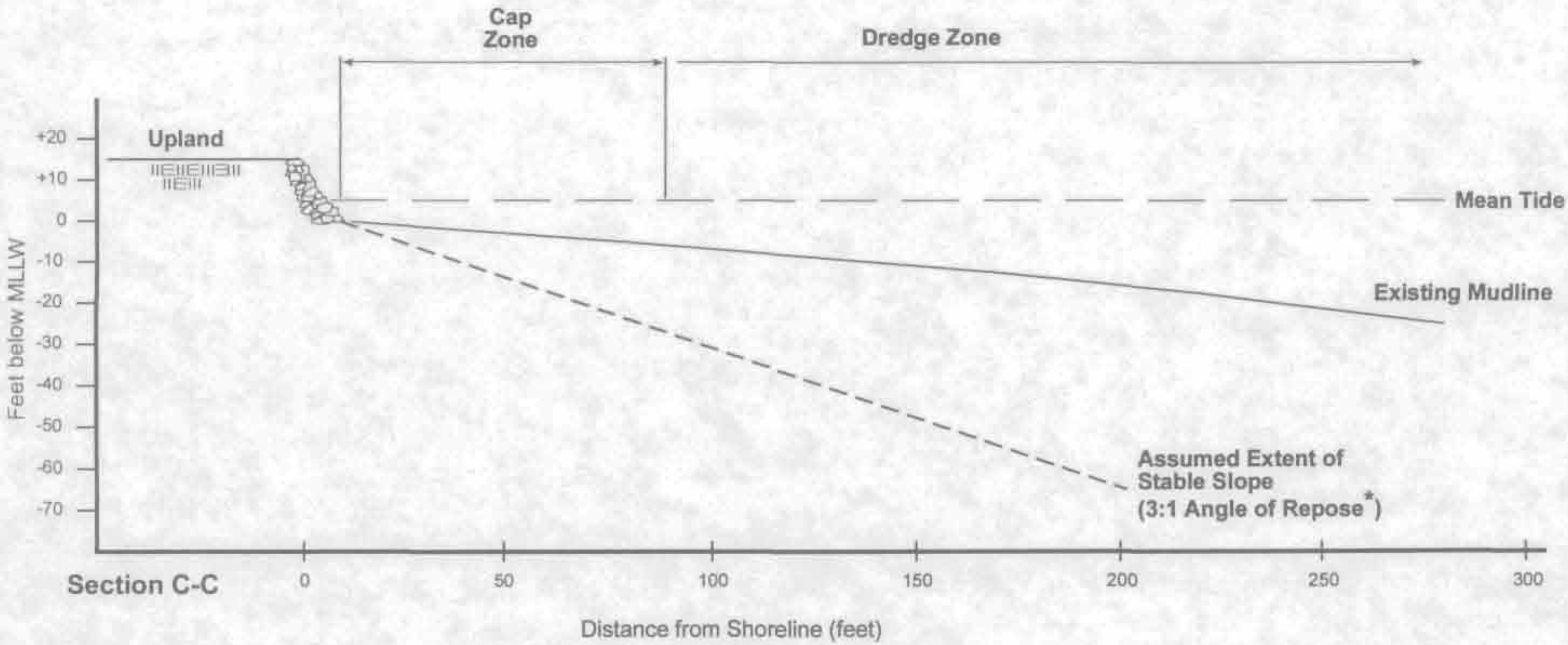
WESTON.

PSR Marine Sediments Unit
Cross-Section B-B

FIGURE

4-4

98-0515 Fig4-4.fh8



Notes: See Figure 4-2 for cross-section locations.

* Corp. of Engineers - Technical Report D-77-9

PSR Marine Sediments Unit
Cross-Section C-C

FIGURE

4-5

WESTON

98-0515 Fig4-5.fh8

SYMBOL EXPLANATION

- Shoreline Cap
- Dredge to CSLs
- Dredge and Cap - Intermediate groundwater discharge zone associated with west-central shoreline wells containing DNAPL
- Cap

GN MN
21°

SCALE 1:2900
50 0 50 100 150 200
Feet

PSR Site

NOTES
See Figure 1-3 for site features notes.

WESTON

DATE: August 27, 1998
JOB NUMBER: 98-0515
VIEW FILE: Fig 4-6.ai7

CHECKED BY: ____________

APPROVED BY: ____________

PSR Marine Sediments Unit
Alternative 2 - Dredging to CSLs

FIGURE
4-6

BASEMAP EXPLANATION

Capping-phase 1

Capping-phase 2

Capping-phase 3

SYMBOL EXPLANATION

Shoreline Cap

Cap

Dredge and Cap Crowley Marine

Cap - Intermediate groundwater discharge zone associated with west-central shoreline wells containing DNAPL

GN MN
21°

SCALE 1:2900
50 0 50 100 150 200
Feet

PSR Site

NOTES

See Figure 1-3 for site features notes.

WESTON

DATE: March 09, 1998 1:44 PM
JOB NUMBER: 98-0515
VIEW FILE: Fig4-7.fh8

CHECKED BY: ____________

APPROVED BY: ____________

PSR Marine Sediments Unit
Alternative 3a – Capping to SQS

FIGURE
4-7

BASEMAP EXPLANATION

Capping-phase 1

Capping-phase 2

SYMBOL EXPLANATION

Shoreline Cap

Cap

Dredge and Cap Crowley Marine

Cap - Intermediate groundwater discharge zone associated with west-central shoreline wells containing DNAPL

GN MN

21°

SCALE 1:2900

50 0 50 100 150 200

Feet

PSR Site

NOTES

See Figure 1-3 for site features notes.

WESTON

DATE: August 27, 1998
JOB NUMBER: 98-0515
VIEW FILE: Fig4-8.fh8

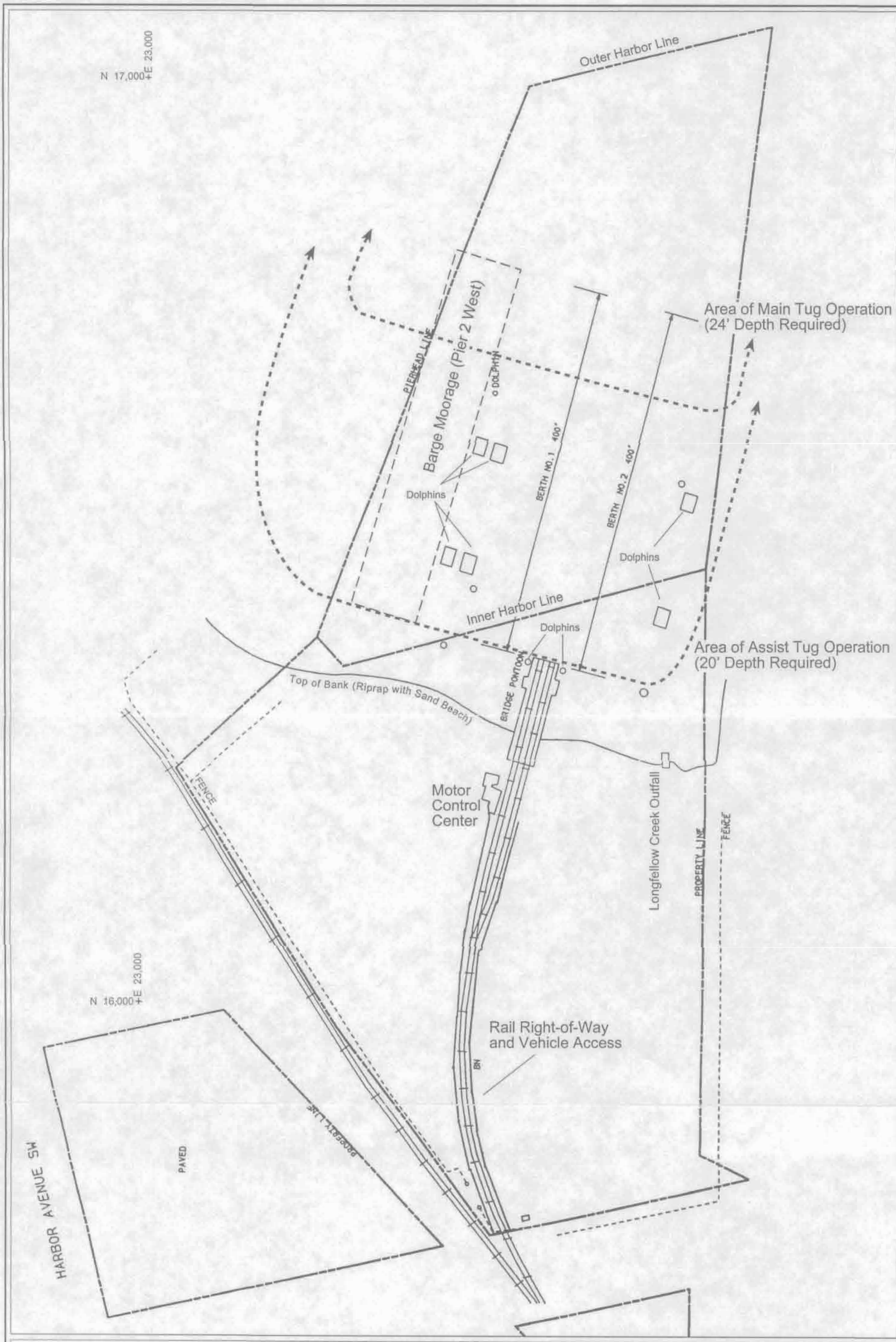
CHECKED BY: __________

APPROVED BY: __________

PSR Marine Sediments Unit
Alternative 3b - Capping to CSLs

FIGURE

4-8



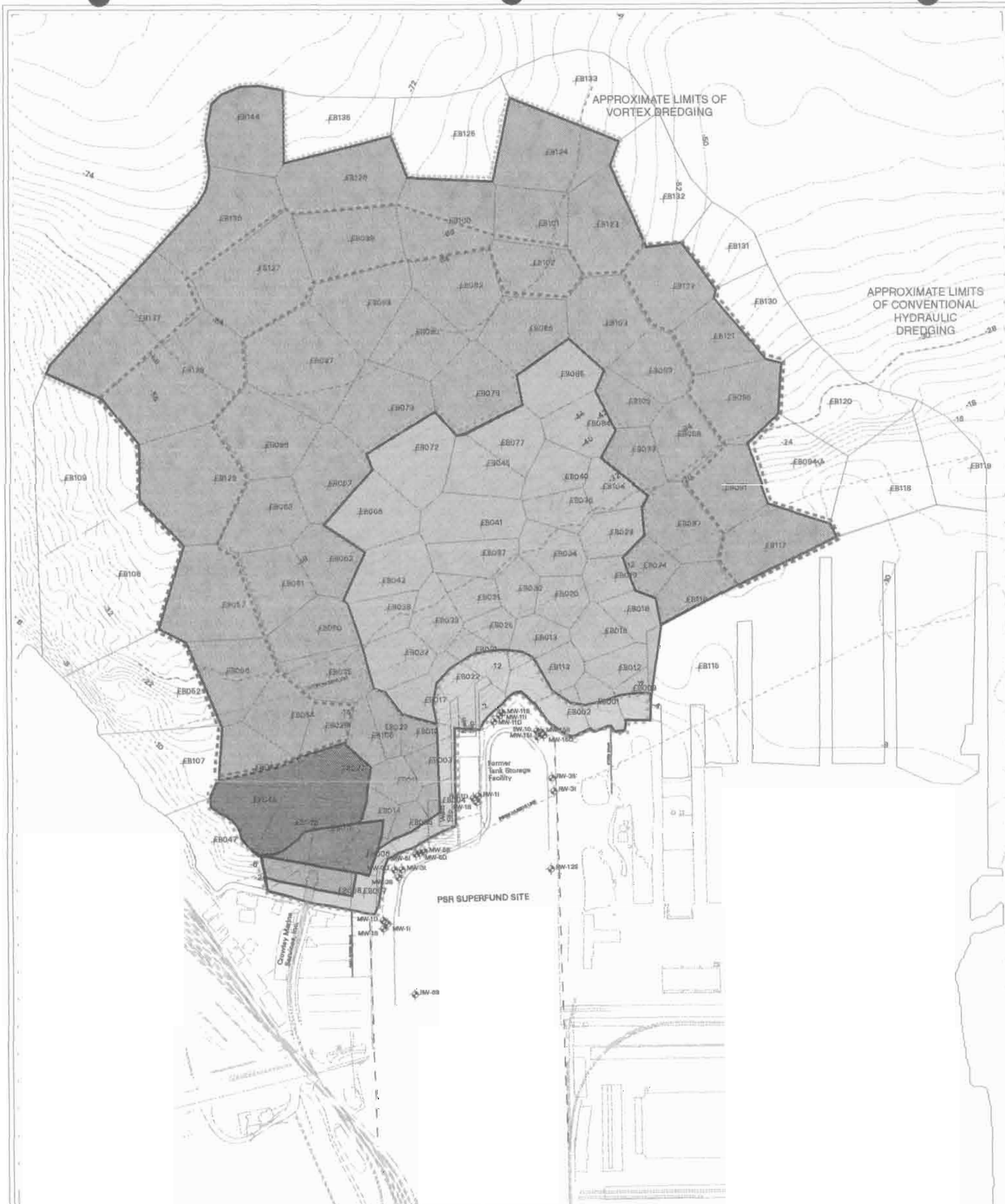
0 50 100
Scale in Feet

WESTON

Crowley Marine Services
Site Detail

FIGURE
4-9

98-0515 Fig4-9.FH8



BASEMAP EXPLANATION

Capping-phase 1

Capping-phase 2

Capping-phase 3

SYMBOL EXPLANATION

Shoreline Cap

Dredge to SQS

Cap

Dredge and Cap Crowley Marine

Dredge and Cap - Intermediate groundwater discharge zone associated with west-central shoreline wells containing DNAPL

GN MN

21°

SCALE 1:2900

50 0 50 100 150 200

Feet

PSR Site

NOTES

See Figure 1-3 for site features notes.

WESTON

DATE: March 09, 1998 1:44 PM
JOB NUMBER: 98-0515
VIEW FILE: Fig4-10.fh8
CHECKED BY: ____________
APPROVED BY: ____________

PSR Marine Sediments Unit Alternative 4a – Fill Area Removal to SQS and Capping

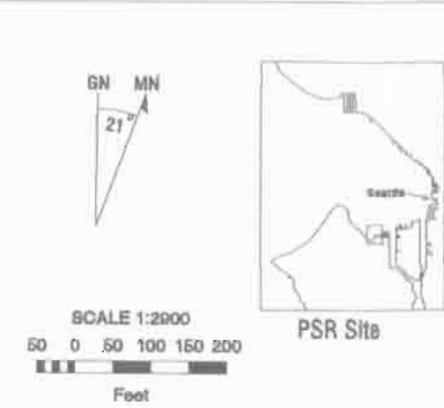
FIGURE
4-10

BASEMAP EXPLANATION

Capping-phase 1

SYMBOL EXPLANATION

- Shoreline Cap
- Dredge to CSL's
- Cap
- Dredge and Cap Crowley Marine
- Dredge and Cap - Intermediate groundwater discharge zone associated with west-central shoreline wells containing DNAPL



NOTES

See Figure 1-3 for site features notes.

WESTON

DATE: March 09, 1998 1:44 PM
JOB NUMBER: 98-0515
VIEW FILE: Fig4-11.fh8

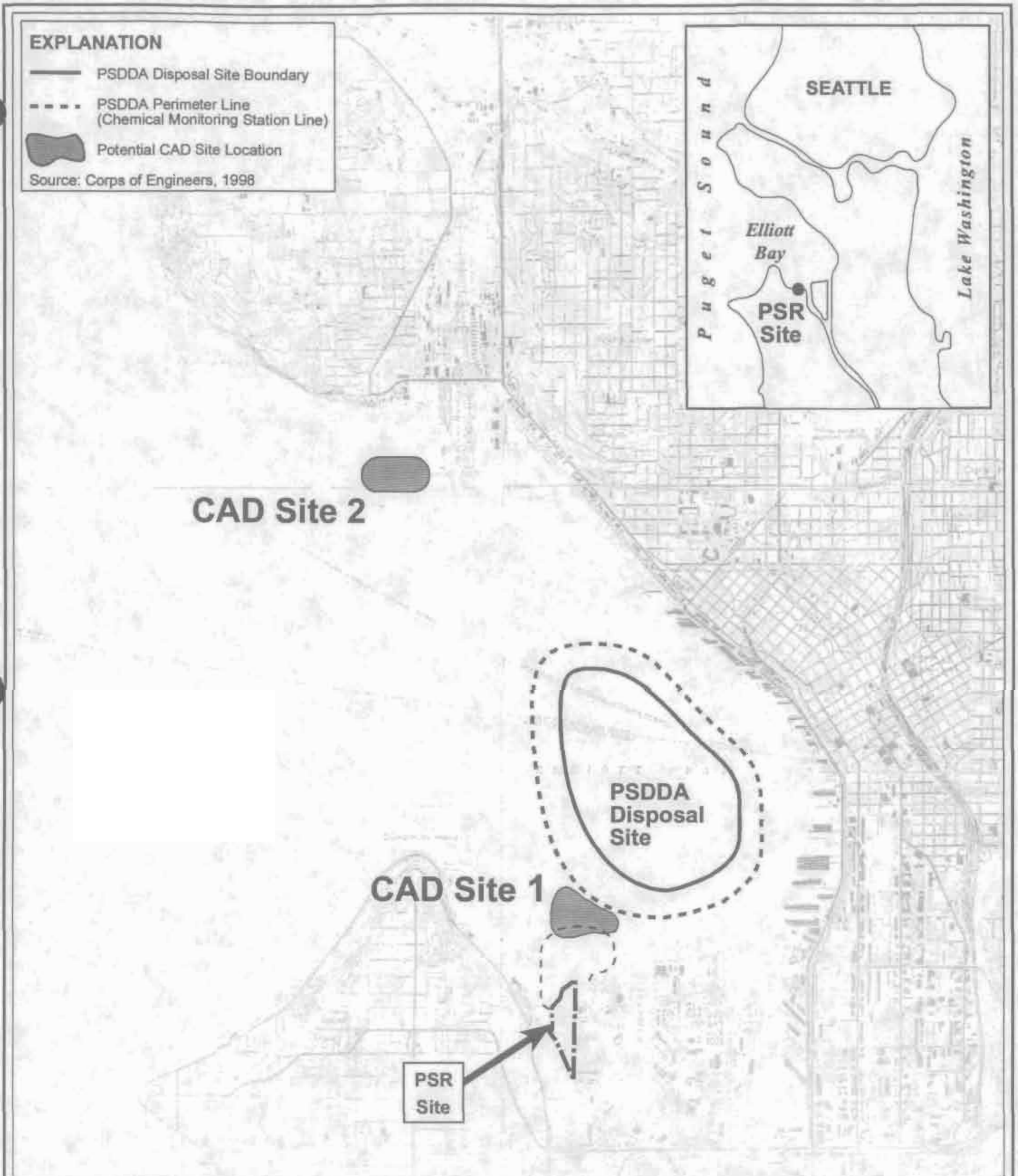
CHECKED BY:

APPROVED BY:

PSR Marine Sediments Unit Alternative 4b – Fill Area Removal to CSLs and Capping

FIGURE

4-11

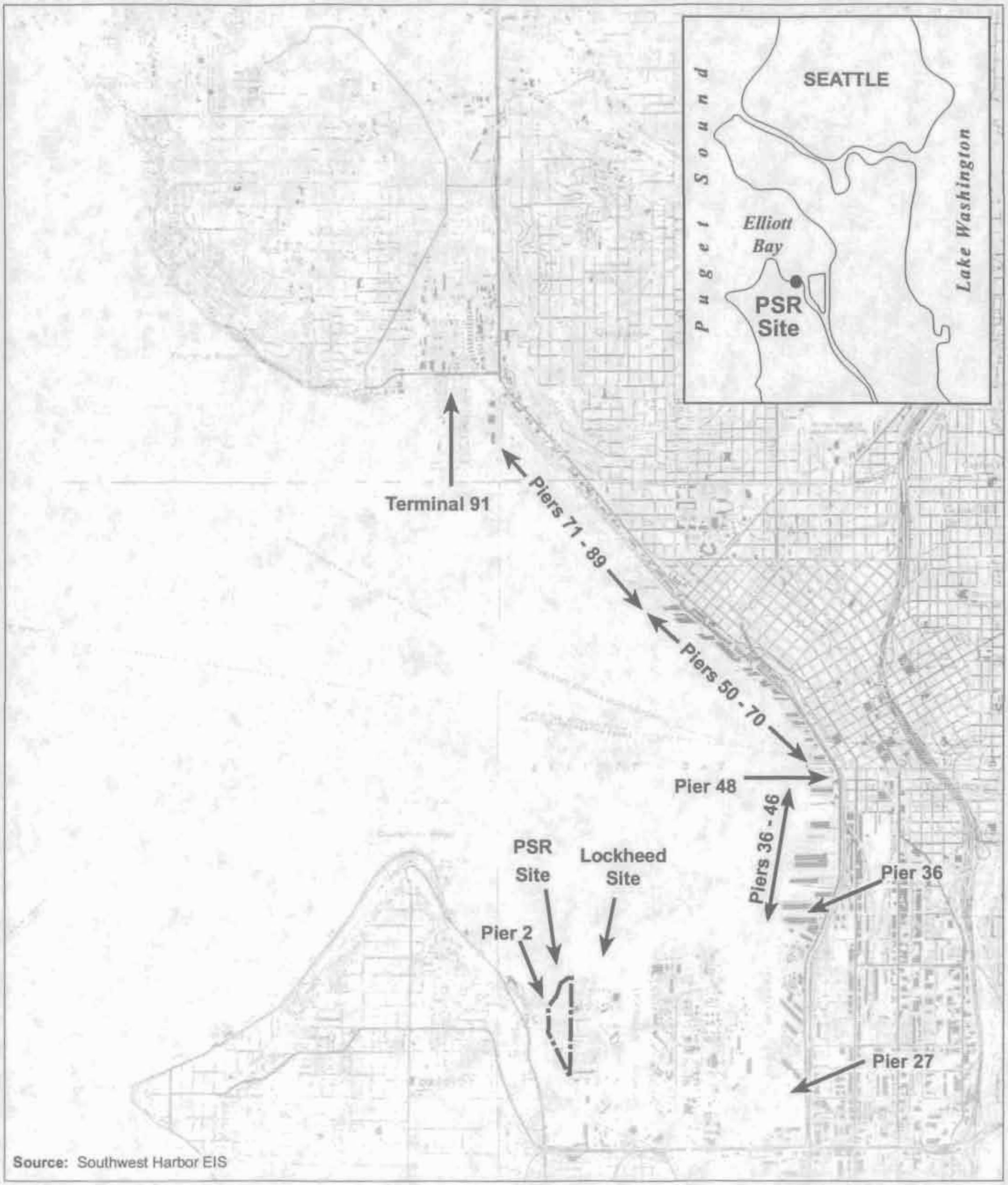


Locations of Potential Confined Aquatic Disposal (CAD) Sites

WESTON

FIGURE 4-12

98-0515 Fig4-12.FH8

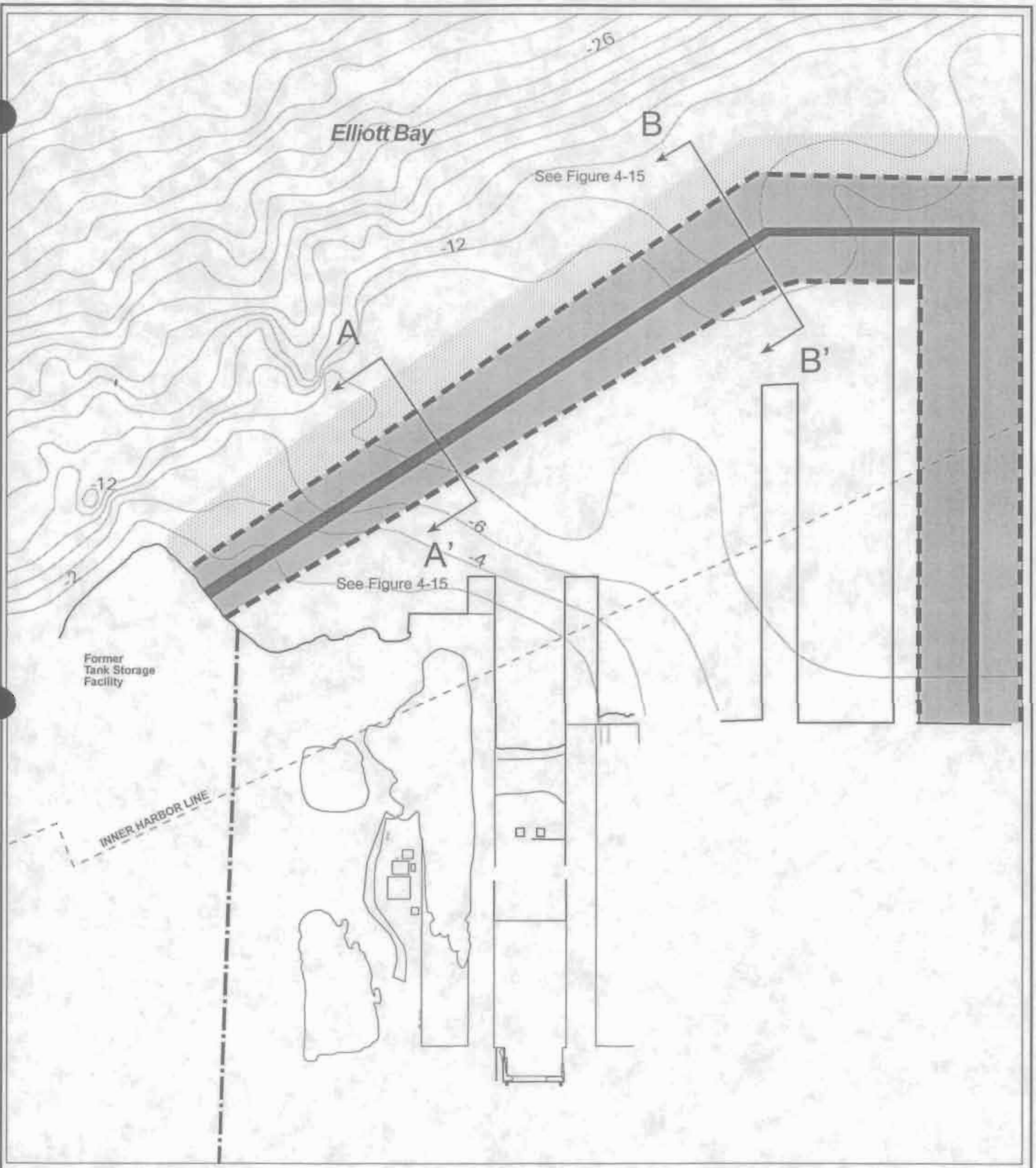


WESTON

Locations of Potential Nearshore Disposal Sites

FIGURE 4-13

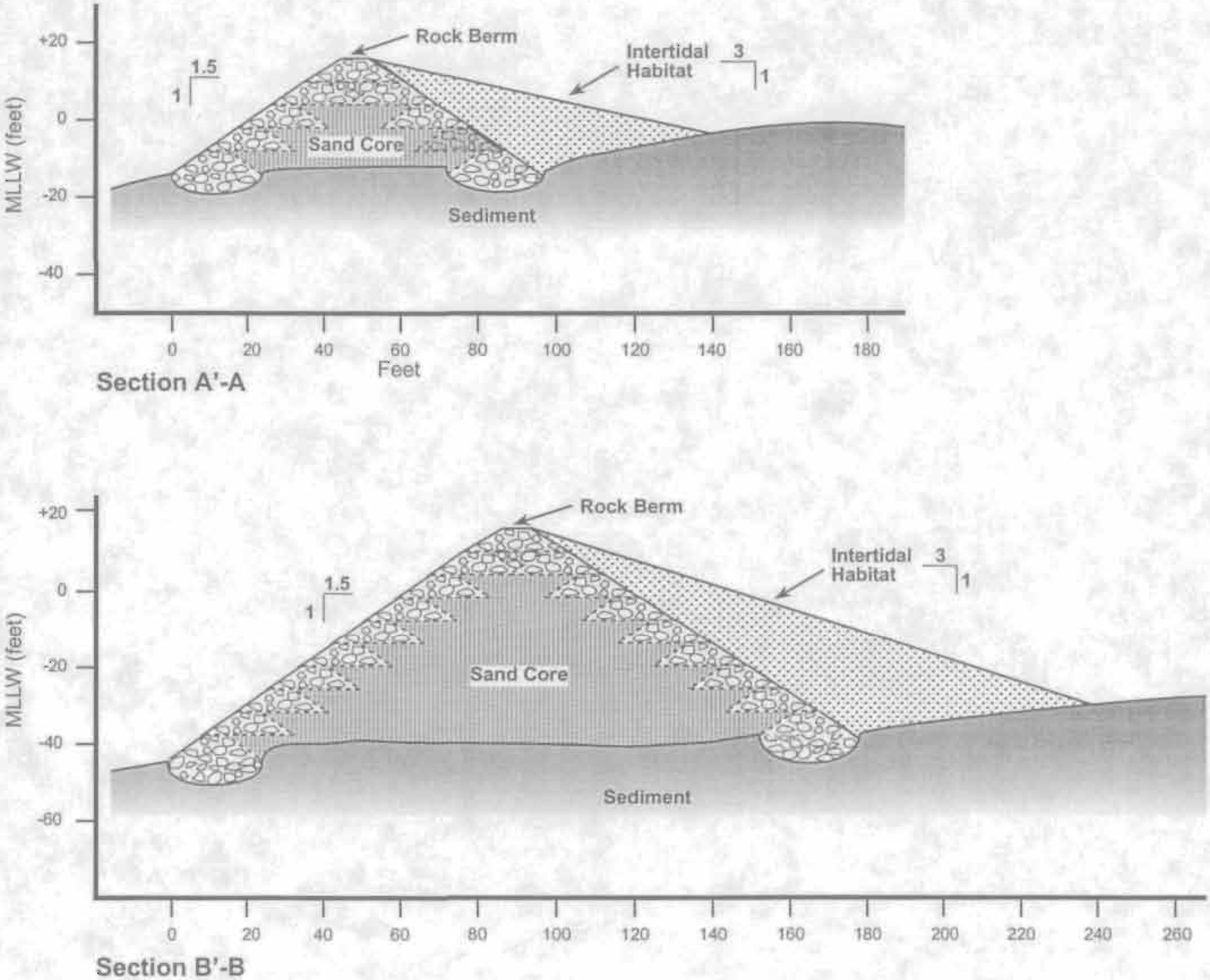
98-0515 Fig4-13.FH8



PSR Marine Sediments Unit
Nearshore Disposal Configuration A
480,000 Cubic Yard Capacity

FIGURE
4-14

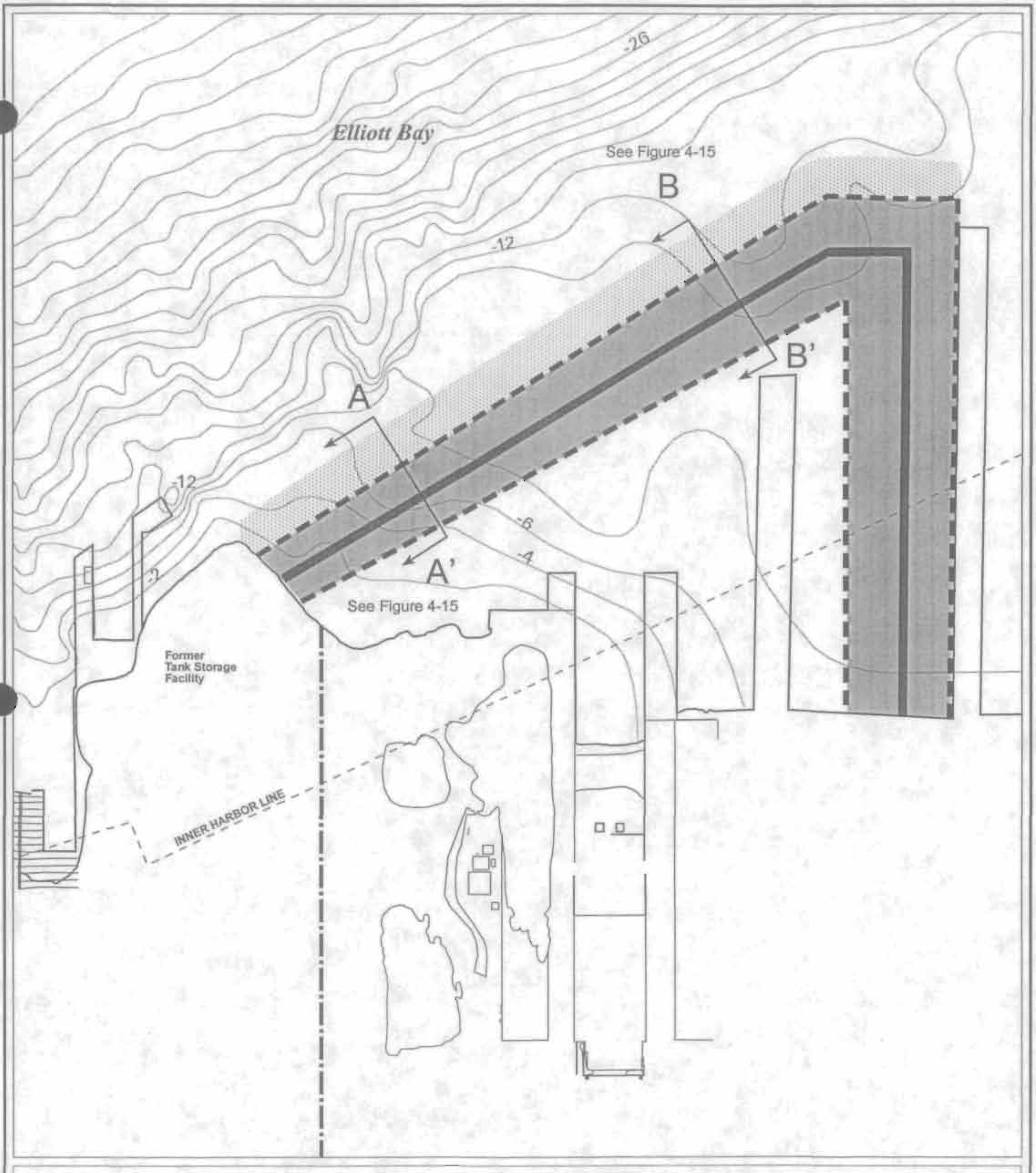
98-0515 Fig4-14.fh8



PSR Marine Sediments Unit
Berm Cross-Sections

FIGURE

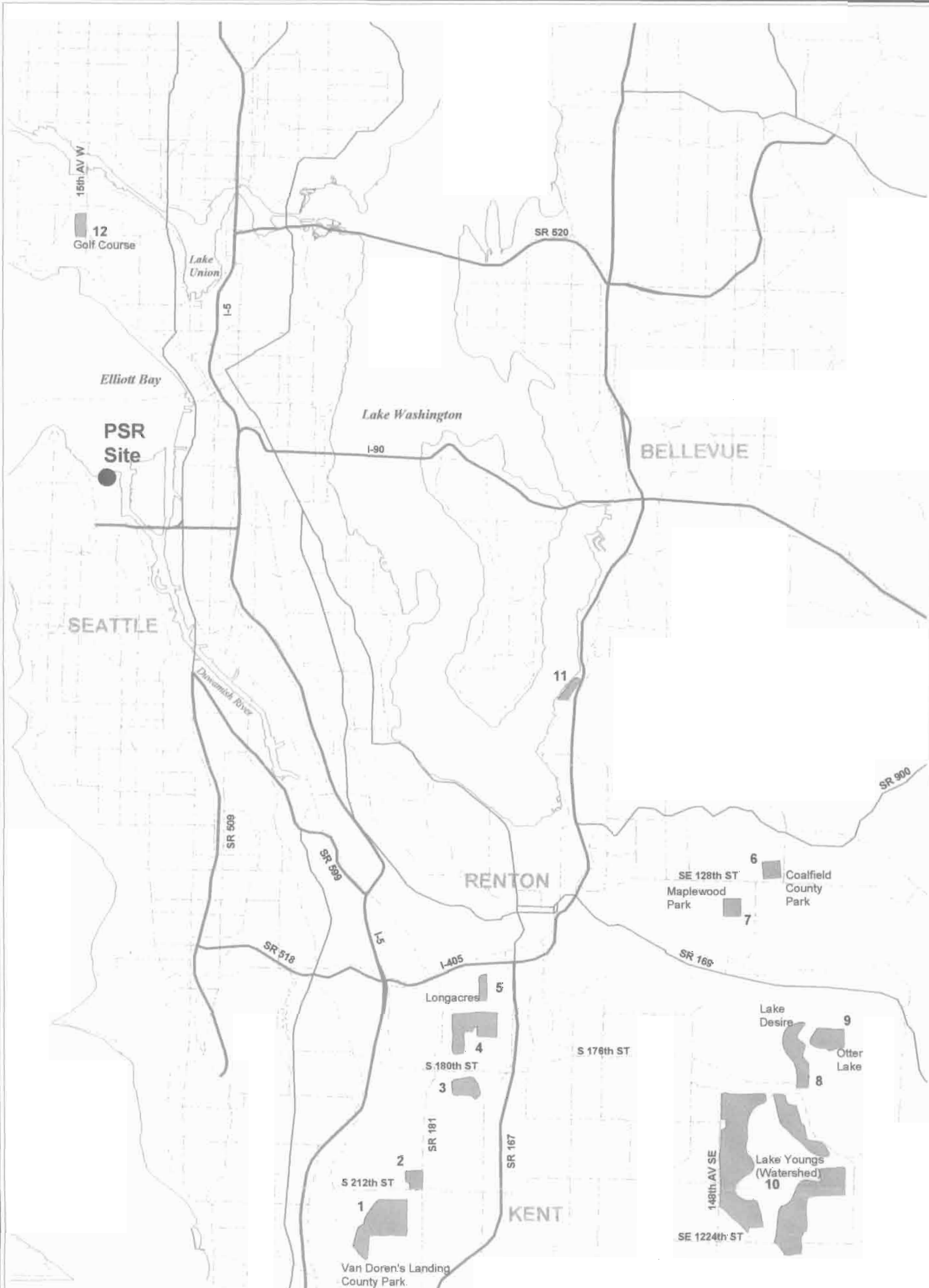
4-15



PSR Marine Sediments Unit
Nearshore Disposal Configuration B
350,000 Cubic Yard Capacity

FIGURE
4-16

98-0515 Fig4-16.fh8



Source: Corps of Engineers, 1998

2000 0 4000 Feet

WESTON

Q:\erns\psr\disposal\98-0361.apr

PSR Marine Sediments Unit
Potential Upland Disposal Sites

FIGURE
4-17

BASEMAP EXPLANATION

Capping-phase 1

Capping-phase 2

SYMBOL EXPLANATION

Shoreline Cap

Cap

Dredge and Cap Crowley Marine

Cap - Intermediate groundwater discharge zone associated with west-central shoreline wells containing DNAPL

GN MN 21°

SCALE 1:2900

50 0 50 100 150 200

Feet

PSR Site

NOTES

See Figure 1-3 for site features notes.

WESTON

DATE: August 27, 1998
JOB NUMBER: 98-0515
VIEW FILE: Fig6-1.th6
CHECKED BY:
APPROVED BY:

PSR Marine Sediments Unit
Modified Alternative 3b—
Capping to CSLs

FIGURE
6-1

TABLES

Table 2-1—SMS and AET Chemical Screening Criteria for Sediment COCs

Chemical	Sediment Management Standards[a]		Apparent Effects Threshold[k]	
	SQS[b]	CSL/MCUL[c]	LAET[i]	2LAET[j]
Organics (ug/kg)				
Acenaphthylene	66,000[e]	66,000[e]	1,300[h]	1,300[h]
Acenaphthene	16,000[e]	57,000[e]	500[h]	730[h]
Anthracene	220,000[e]	1,200,000[e]	960[h]	4,400[h]
Benz(a)anthracene	110,000[e]	270,000[e]	1,300[h]	1,600[h]
Benzo(a)pyrene	99,000[e]	210,000[e]	1,600[h]	3,000[h]
Total Benzofluoranthenes[g]	230,000[e]	450,000[e]	3,200[h]	3,600[h]
Benzo(g,h,i)perylene	31,000[e]	78,000[e]	670[h]	720[h]
Chrysene	110,000[e]	460,000[e]	1,400[h]	2,800[h]
Dibenz(a,h)anthracene	12,000[e]	33,000[e]	230[h]	540[h]
Dibenzofuran	15,000[e]	58,000[e]	540[h]	700[h]
2,4-Dimethylphenol	29[h]	29[h]	29[h]	72[h]
Fluoranthene	160,000[e]	1,200,000[e]	1,700[h]	2,500[h]
Fluorene	23,000[e]	79,000[e]	540[h]	1,000[h]
Total HPAH	960,000[e,f]	5,300,000[e,f]	12,000[h]	17,000[h]
Indeno(1,2,3-cd)pyrene	34,000[e]	88,000[e]	600[h]	690[h]
Total LPAH	370,000[d,e]	780,000[d,e]	5200[h]	13,000[h]
2-Methylnaphthalene	38,000[e]	64,000[e]	670[h]	1,400[h]
2-Methylphenol	63[h]	63[h]	63[h]	72[h]
4-Methylphenol	670[h]	670[h]	670[h]	1,800[h]
Naphthalene	99,000[e]	170,000[e]	2,100[h]	2,400[h]
Total PCBs[l]	12,000[e]	65,000[e]	130[h]	1,000[h]
Pentachlorophenol	360[h]	690[h]	360[h]	690[h]
Phenanthrene	100,000[e]	480,000[e]	1,500[h]	5,400[h]
Phenol	420[h]	1,200[h]	420[h]	1,200[h]
Pyrene	1,000,000[e]	1,400,000[e]	2,600[h]	3,300[h]
Inorganics (mg/kg)				
Arsenic	57[h]	93[h]	57[h]	93[h]
Cadmium	5.1[h]	6.7[h]	5.1[h]	6.7[h]
Chromium (total)	260[h]	270[h]	260[h]	270[h]
Copper	390[h]	390[h]	390[h]	530[h]
Lead	450[h]	530[h]	450[h]	530[h]

Table 2-1—SMS and AET Chemical Screening Criteria for Sediment COCs

Chemical	Sediment Management Standards[a]		Apparent Effects Threshold[k]	
	SQS[b]	CSL/MCUL[c]	LAET[i]	2LAET[j]
Mercury	0.41[h]	0.59[h]	0.41[h]	0.59[h]
Zinc	410[h]	960[h]	410[h]	960[h]

[a]Chapter 173-204 WAC.
[b]Sediment quality standards.
[c]Cleanup screening levels and minimum cleanup levels.
[d]This value represents the sum of the following compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene; the LPAH criterion does not represent the sum of the criteria values for the individual compounds.
[e]Normalized to total organic carbon content.
[f]This value represents the sum of the following compounds: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3 cd)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene; the HPAH criterion does not represent the sum of the criteria values for the individual compounds.
[g]Sum of the concentrations of the "b," "j," and "k" isomers.
[h]Dry-weight basis.
[i]Lowest Apparent Effects Threshold.
[j]Second-lowest Apparent Effects Threshold.
[k]Barrick et al., 1988.
[l]This value represents the sum of detected aroclors.

Table 2-2—Surface Sediment Background Concentrations of 2,3,7,8-TCDD (Equiv.)[a]

Compound	Concentration						
	Phase 1				Phase 2		
	BK01	BK01D[b]	BK02	BK03	BK01	BK04	Average
2,3,7,8-TCDD Eqiv. (ng/kg DW)	0.619	0.518	4.029	0.184	0.290	0.670	1.052
2,3,7,8-TCDD Eqiv. (ng/kg TOCN)	82.5	55.10	366.30	NA	12.1	95.7	122.34

[a]Methods used for deriving and summing 2,3,7,8-TCDD equivalents are described in **Appendix F**.

[b]Field replicate at Station BK01.

DW: Dry-weight.

TOCN: Normalized to total organic carbon (TOC) content.

NA: Normalization not appropriate; TOC content less than 0.5 percent.

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Table 2-3—Summary Statistics for Surface Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations: Dry-Weight Minimum	Dry-Weight Maximum	Dry-Weight Location of Maximum	TOC-Normalized Minimum	TOC-Normalized Maximum	TOC-Normalized Location of Maximum	# of Stations Exceeding Screening Criteria: SQS/LAET[c]	CSL/2LAET[c]	Frequency of Exceedance of Screening Criteria (%)[b]: SQS/LAET	CSL/2LAET	Average CSL/2LAET ER[a]
PAHs (ug/kg)														
Naphthalene	106	104	98	38	85,700	EB09	3,324	2,818,182	EB05	59	38	56	36	3.55
Acenaphthylene	106	106	100	10	8,380	EB13	676	82,174	EB27	4	4	4	4	1.18
Acenaphthene	106	105	99	20	397,000	EB13	1,448	766,234	EB05	83	46	78	43	3.81
Fluorene	106	106	100	21	218,000	EB13	2,133	760,000	EB19	74	36	70	34	3.04
Phenanthrene	106	106	100	96	549,000	EB13	9,857	3,468,750	EB02	64	17	60	16	2.49
Anthracene	106	106	100	42	1,750,000	EB13	4,552	1,900,000	EB02	17	5	16	5	1.39
Total LPAH	106	106	100	248	2,948,080	EB13	21,990	6,988,052	EB05	59	36	56	34	2.74
Fluoranthene	106	106	100	164	2,060,000	EB13	19,095	8,695,652	EB27	57	13	54	12	2.99
Pyrene	106	106	100	187	1,140,000	EB13	16,048	6,956,522	EB27	17	14	16	13	2.59
Benzo(a)anthracene	106	106	100	61	382,000	EB13	11,714	1,891,304	EB27	26	12	25	11	2.56
Chrysene	106	106	100	100	526,000	EB13	16,238	1,860,870	EB27	44	10	42	9	2.24
Total Benzofluoranthenes	106	106	100	177	302,900	EB13	27,333	1,743,478	EB27	32	16	30	15	1.56
Benzo(a)pyrene	106	106	100	84	114,000	EB13	12,857	726,087	EB27	29	11	27	10	1.62
Indeno(1,2,3-cd)pyrene	106	106	100	45	34,400	EB13	6,190	215,652	EB27	41	9	39	8	1.50
Dibenz(a,h)anthracene	106	99	93	4.2	10,700	EB13	1,029	79,130	EB27	30	7	28	7	1.49
Benzo(g,h,i)perylene	106	106	100	46	26,600	EB13	5,238	177,826	EB27	41	7	39	7	1.61
Total HPAH	106	106	100	869	4,596,600	EB13	117,257	22,346,522	EB27	48	11	45	10	2.03
2-Methylnaphthalene	106	105	99	16	26,000	EB13	1,119	646,753	EB05	42	31	40	29	2.26
OTHER SVOCs (ug/kg)														
2,4-Dimethylphenol	44	26	59	21	1,310	EB09	--	--	--	23	23	52	52	
2-Methylphenol	44	31	70	7.2	601	EB09	--	--	--	6	6	14	14	
4-Methylphenol	44	43	98	17	6,770	EB02	--	--	--	4	4	9	9	
Pentachlorophenol	44	8	18	158	380	EB24	--	--	--	1	0	2	0	
Phenol	44	30	68	22	3,980	EB02	--	--	--	3	1	7	2	
Dibenzofuran	67	67	100	40	62,800	EB13	1,895	800,000	EB19	54	29	81	43	3.53
2-Chloronaphthalene	51	0	0	<3.5	<149	--	--	--	--	--	--	--	--	--
Carbazole	51	46	90	13	3,090	EB87	--	--	--	--	--	--	--	--
1-Methylnaphthalene	28	28	100	31	4,570	EB87	--	--	--	--	--	--	--	--
Retene	28	28	100	115	635	EB87	--	--	--	--	--	--	--	--
PCBs (ug/kg)														
Total PCBs	42	42	100	24	1,340	EB06	3,923	78,182	EB08	25	2	60	5	1.14
DIOXINS/FURANS (ng/kg)														
2,3,7,8-TCDD (Equiv.)	38	38	100	1.97	156	EB26	102	11,819	EB05	--	--	--	--	--

Table 2-3—Summary Statistics for Surface Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations: Dry-Weight Minimum	Dry-Weight Maximum	Dry-Weight Location of Maximum	TOC-Normalized Minimum	TOC-Normalized Maximum	TOC-Normalized Location of Maximum	# of Stations Exceeding Screening Criteria: SQS/LAET[c]	CSL/2LAET[c]	Frequency of Exceedance of Screening Criteria (%)[b]: SQS/LAET	CSL/2LAET	Average CSL/2LAET ER[a]
INORGANICS (mg/kg)														
Arsenic	44	39	89	4.7	24	EB13	--	--	--	0	0	0	0	--
Cadmium	44	37	84	0.38	2.7	EB08	--	--	--	0	0	0	0	--
Chromium	44	44	100	9.2	251	EB09	--	--	--	0	0	0	0	--
Copper	44	44	100	12	410	EB01	--	--	--	1	1	2	2	1.05
Lead	44	44	100	6.7	192	EB09	--	--	--	0	0	0	0	--
Mercury	53	53	100	0.02	4.2	EB12	--	--	--	19	11	36	21	1.98
Zinc	44	44	100	35	639	EB27	--	--	--	3	0	7	0	--

--: Not applicable.

<: Not detected at dry-weight detection limit shown.

[a]Average ERs calculated using only those individual ERs >1.0 and excluding stations EB09 and EB13; these two stations were consistently characterized by chemical concentrations orders of magnitude above 2LAET screening values, which substantially skewed the average values and effectively masked any apparent differences or trends in contaminant distribution.

[b]Frequencies based on total number of stations analyzed.

[c]The nonionic/nonpolar organic chemical data for the following stations were compared with AETs based on TOC content outside the range determined to be appropriate for normalization (see also Appendix F): EB04, EB09, EB13, EB28, EB34, EB37, EB94.

Table 2-4—Summary Statistics for Shallow Subsurface (0 to 20 feet bgs) Sediment COCs

Constituent	# of Core Intervals Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations						# of Core Intervals Exceeding Screening Criteria		Frequency of Exceedance of Screening Criteria (%)[b]		Average CSL/2LAET ER[a]
				Dry-Weight			TOC-Normalized							
				Minimum	Maximum	Location of Maximum	Minimum	Maximum	Location of Maximum	SQS/LAET[c]	CSL/2LAET[c]	SQS/LAET	CSL/2LAET	
PAHs (ug/kg)														
Naphthalene	65	56	86	4.0	3,310,000	EB13-0000A	588	91,142,857	EB27-0080	29	26	45	40	98.23
Acenaphthylene	65	39	60	1.4	33,800	EB27-0080	240	965,714	EB27-0080	9	9	14	14	4.20
Acenaphthene	65	54	83	2.1	1,490,000	EB27-0080	339	42,571,429	EB27-0080	36	30	55	46	131.79
Fluorene	65	51	78	5.0	1,490,000	EB27-0080	806	42,571,429	EB27-0080	34	29	52	45	80.15
Phenanthrene	65	60	92	4.2	3,750,000	EB27-0080	1,069	107,142,857	EB27-0080	32	21	49	32	61.89
Anthracene	65	61	94	1.2	1,950,000	EB13-0000A	271	11,600,000	EB27-0080	18	11	28	17	59.05
Total LPAH	65	63	97	1.2	10,359,800	EB27-0080	291	295,994,286	EB27-0080	32	25	49	38	73.11
Fluoranthene	65	57	88	7.8	1,530,000	EB27-0080	1,300	43,714,286	EB27-0080	28	18	43	28	56.49
Pyrene	65	62	95	4.0	933,000	EB27-0080	909	26,657,143	EB27-0080	19	16	29	25	27.95
Benzo(a)anthracene	65	45	69	4.7	221,000	EB27-0080	1,784	6,314,286	EB27-0080	20	16	31	25	16.04
Chrysene	65	49	75	2.6	201,000	EB27-0080	371	5,742,857	EB27-0080	21	14	32	22	10.69
Total Benzofluoranthenes	65	51	78	3.6	147,900	EB27-0080	1,055	4,225,714	EB27-0080	19	14	29	22	5.32
Benzo(a)pyrene	65	40	62	6.1	61,700	EB27-0080	813	1,762,857	EB27-0080	20	13	31	20	3.36
Indeno(1,2,3-cd)pyrene	65	43	66	2.7	17,700	EB27-0080	397	505,714	EB27-0080	20	7	31	11	5.38
Dibenz(a,h)anthracene	65	34	52	1.7	6,210	EB27-0080	304	177,429	EB27-0080	18	8	28	12	3.22
Benzo(g,h,i)perylene	65	42	65	2.9	14,400	EB27-0080	426	411,429	EB27-0080	20	8	31	12	3.70
Total HPAH	65	62	95	4.0	3,132,910	EB27-0080	909	89,511,714	EB27-0080	26	15	40	23	20.60
2-Methylnaphthalene	65	61	94	1.2	1,570,000	EB27-0080	200	44,857,143	EB27-0080	28	25	43	38	75.81
OTHER SVOCs (ug/kg)														
2,4-Dimethylphenol	10	2	20	316	3,680	EB13-0000A	--	--	--	2	2	20	20	68.89
2-Methylphenol	10	0	0	<9.1	<335	--	--	--	--	0	0	0	0	--
4-Methylphenol	10	3	30	107	2,060	EB13-0000A	--	--	--	1	1	10	10	3.07
Pentachlorophenol	10	0	0	<18	<670	--	--	--	--	0	0	0	0	--
Phenol	10	0	0	<9.1	<335	--	--	--	--	0	0	0	0	--
Dibenzofuran	10	8	80	27	612,000	EB13-0000A	15,778	3,013,158	EB13-0080	6	5	60	50	198.13
2-Chloronaphthalene	49	1	2	10,600	10,600	EB72-0000A	--	--	--	--	--	--	--	--
Carbazole	49	30	61	0.003	95,400	EB27-0080	--	--	--	--	--	--	--	--
1-Methylnaphthalene	59	57	97	1.2	897,000	EB27-0080	--	--	--	--	--	--	--	--
Retene	49	49	100	12	83,300	EB113-0040	--	--	--	--	--	--	--	--
PCBs (ug/kg)														
Total PCBs	10	1	10	291	291	EB13-0000A	--	--	--	1	0	10	0	--

Table 2-4—Summary Statistics for Shallow Subsurface (0 to 20 feet bgs) Sediment COCs

Constituent	# of Core Intervals Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations: Dry-Weight Minimum	Dry-Weight Maximum	Dry-Weight Location of Maximum	TOC-Normalized Minimum	TOC-Normalized Maximum	TOC-Normalized Location of Maximum	# of Core Intervals Exceeding Screening Criteria: SQS/LAET[c]	CSL/2LAET[c]	Frequency of Exceedance of Screening Criteria (%)[b]: SQS/LAET	CSL/2LAET	Average CSL/2LAET ER[a]
INORGANICS (mg/kg)														
Arsenic	10	7	70	4.5	11.0	EB13-0000A	--	--	--	0	0	0	0	--
Cadmium	10	2	20	0.34	1.6	EB13-0000A	--	--	--	0	0	0	0	--
Chromium	10	10	100	10	67	EB13-0000A	--	--	--	0	0	0	0	--
Copper	10	10	100	7.6	62	EB13-0000A	--	--	--	0	0	0	0	--
Lead	10	10	100	3.0	102.0	EB41-0000A	--	--	--	0	0	0	0	--
Mercury	10	9	90	0.023	0.71	EB13-0000A	--	--	--	1	1	10	10	1.20
Nickel	10	10	100	8.8	26	EB13-0000A	--	--	--	0	0	0	0	--
Zinc	10	10	100	20	252	EB13-0000A	--	--	--	0	0	0	0	--

--: Not applicable: Constituent not detected, screening criteria based on dry-weight data or not available, or TOC content outside range for normalization.

<: Not detected at dry-weight detection limit shown.

[a]Average ERs calculated using only those individual ERs >1.0.

[b]Frequencies based on total number of stations analyzed.

[c]The nonionic/nonpolar organic chemical data for several core intervals were compared with AETs based on TOC content outside the range determined to be appropriate for normalization (see **Table F-1** in **Appendix F** for sample list).

Table 2-5—Summary Statistics for Shallow Subsurface (0 to 4 feet bgs) Sediment COCs

				Detected Concentrations						# of Stations Exceeding Screening Criteria		Frequency of Exceedance of Screening Criteria (%)[a]	
				Dry-Weight			TOC-Normalized						
Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Minimum	Maximum	Location of Maximum	Minimum	Maximum	Location of Maximum	SQS/LAET[b]	CSL/2LAET[b]	SQS/LAET	CSL/2LAET
PAHs (ug/kg)													
Naphthalene	17	17	100	43	3,310,000	EB13	6,358	5,666,667	EB32	15	13	88	76
Acenaphthylene	17	16	94	3.5	14,100	EB13	522	80,000	EB32	3	3	18	18
Acenaphthene	17	17	100	16	833,000	EB113	2,388	5,541,667	EB32	16	13	94	76
Fluorene	17	17	100	30	821,000	EB13	4,463	6,625,000	EB32	15	12	88	71
Phenanthrene	17	17	100	150	2,290,000	EB13	22,388	16,833,333	EB32	14	9	82	53
Anthracene	17	17	100	144	1,950,000	EB13	21,493	1,645,833	EB32	7	4	41	24
Total LPAH	17	17	100	386	9,166,100	EB13	57,612	36,392,500	EB32	14	12	82	71
Fluoranthene	17	17	100	404	972,000	EB113	60,299	9,625,000	EB32	13	7	76	41
Pyrene	17	17	100	320	547,000	EB13	47,761	5,375,000	EB32	8	8	47	47
Benzo(a)anthracene	17	17	100	185	174,000	EB13	26,000	1,270,833	EB32	9	7	53	41
Chrysene	17	17	100	406	172,000	EB13	34,100	1,175,000	EB32	9	6	53	35
Total Benzofluoranthenes	17	17	100	125	104,400	EB13	18,582	1,399,231	EB66	10	7	59	41
Benzo(a)pyrene	17	17	100	48	40,600	EB13	7,104	674,615	EB66	9	7	53	41
Indeno(1,2,3-cd)pyrene	17	17	100	16	14,600	EB13	2,388	206,923	EB66	10	5	59	29
Dibenz(a,h)anthracene	17	17	100	5.8	5,800	EB13	866	106,154	EB66	9	5	53	29
Benzo(g,h,i)perylene	17	17	100	13	9,040	EB13	1,896	193,846	EB66	10	4	59	24
Total HPAH	17	17	100	1,570	2,001,440	EB13	234,269	18,992,917	EB32	14	7	82	41
2-Methylnaphthalene	17	17	100	6.8	890,000	EB13	1,015	2,560,000	EB27	14	12	82	71
OTHER SVOCs (ug/kg)													
2,4-Dimethylphenol	2	1	50	3,680	3,680	EB13	–	–	–	1	1	50	50
2-Methylphenol	2	0	0	<57	<335	–	–	–	–	0	0	0	0
4-Methylphenol	2	2	100	107	2,060	EB13	–	–	–	1	1	50	50
Pentachlorophenol	2	0	0	<113	<670	–	–	–	–	0	0	0	0
Phenol	2	0	0	<57	<335	–	–	–	–	0	0	0	0
Dibenzofuran	2	2	100	13,900	612,000	EB13	926,667	926,667	EB41	2	2	100	100
2-Chloronaphthalene	15	1	7	10,600	10,600	EB72	–	–	–	–	–	–	–
Carbazole	15	14	93	2.6	56,000	EB113	–	–	–	–	–	–	–
1-Methylnaphthalene	17	17	100	12	470,000	EB13	–	–	–	–	–	–	–
Retene	15	15	100	55	3,440	EB113	–	–	–	–	–	–	–
PCBs (ug/kg)													
Total PCBs	2	1	50	291	291	EB13	–	–	–	1	0	50	0
INORGANICS (mg/kg)													
Arsenic	2	2	100	4.5	11	EB13	–	–	–	0	0	0	0
Cadmium	2	2	100	0.34	1.6	EB13	–	–	–	0	0	0	0
Chromium	2	2	100	24	67	EB13	–	–	–	0	0	0	0
Copper	2	2	100	36	62	EB13	–	–	–	0	0	0	0

Table 2-5—Summary Statistics for Shallow Subsurface (0 to 4 feet bgs) Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations: Dry-Weight: Minimum	Dry-Weight: Maximum	Dry-Weight: Location of Maximum	TOC-Normalized: Minimum	TOC-Normalized: Maximum	TOC-Normalized: Location of Maximum	# of Stations Exceeding Screening Criteria: SQS/LAET[b]	# of Stations Exceeding Screening Criteria: CSL/2LAET[b]	Frequency of Exceedance of Screening Criteria (%)[a]: SQS/LAET	Frequency of Exceedance of Screening Criteria (%)[a]: CSL/2LAET
Lead	2	2	100	81	102	EB41	--	--	--	0	0	0	0
Mercury	2	2	100	0.30	0.71	EB13	--	--	--	1	1	50	50
Nickel	2	2	100	21	26	EB13	--	--	--	0	0	0	0
Zinc	2	2	100	62	252	EB13	--	--	--	0	0	0	0

--: Not applicable: Constituent not detected, screening criteria based on dry-weight data or not available, or TOC content outside range for normalization.

<: Not detected at dry-weight detection limit shown.

[a]Frequencies based on total number of stations analyzed.

[b]The nonionic/nonpolar organic chemical data for several core intervals were compared with AETs based on TOC content outside the range determined to be appropriate for normalization (see Table F-1 in Appendix F for sample list).

Table 2-6—Summary Statistics for Shallow Subsurface (4 to 8 feet bgs) Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations: Dry-Weight Minimum	Dry-Weight Maximum	Dry-Weight Location of Maximum	TOC-Normalized Minimum	TOC-Normalized Maximum	TOC-Normalized Location of Maximum	# of Stations Exceeding Screening Criteria SQS/LAET[b]	# of Stations Exceeding Screening Criteria CSL/2LAET[b]	Frequency of Exceedance of Screening Criteria (%)[a] SQS/LAET	Frequency of Exceedance of Screening Criteria (%)[a] CSL/2LAET
PAHs (ug/kg)													
Naphthalene	17	16	94	10	326,000	EB27	1,467	10,181,818	EB13	8	7	47	41
Acenaphthylene	17	13	76	1.4	2,160	EB113	240	69,091	EB13	2	2	12	12
Acenaphthene	17	15	88	2.1	208,000	EB27	347	6,303,030	EB27	10	9	59	53
Fluorene	17	13	76	9.5	210,000	EB27	1,080	6,363,636	EB27	10	9	59	53
Phenanthrene	17	15	88	17	492,000	EB27	2,240	14,909,091	EB27	9	7	53	41
Anthracene	17	16	94	2.6	143,000	EB113	800	2,095,238	EB66	7	4	41	24
Total LPAH	17	16	94	22	1,287,720	EB27	5,173	39,021,818	EB27	9	7	53	41
Fluoranthene	17	16	94	7.8	311,000	EB113	2,909	7,253,968	EB66	8	6	47	35
Pyrene	17	17	100	8.3	171,000	EB113	3,418	5,253,968	EB66	7	5	41	29
Benzo(a)anthracene	17	13	76	14	34,600	EB113	1,784	1,761,905	EB66	7	6	41	35
Chrysene	17	14	82	6.6	40,100	EB113	880	3,333,333	EB66	8	5	47	29
Total Benzofluoranthenes	17	16	94	4.6	20,440	EB27	1,055	1,028,571	EB66	6	4	35	24
Benzo(a)pyrene	17	11	65	6.1	9,140	EB27	813	422,222	EB66	8	3	47	18
Indeno(1,2,3-cd)pyrene	17	12	71	3.1	2,730	EB27	413	86,032	EB66	5	2	29	12
Dibenz(a,h)anthracene	17	9	53	1.7	948	EB27	304	35,873	EB66	6	1	35	6
Benzo(g,h,i)perylene	17	11	65	3.8	2,200	EB27	507	80,476	EB66	6	2	35	12
Total HPAH	17	17	100	8.3	584,321	EB113	7,382	19,256,349	EB66	8	5	47	29
2-Methylnaphthalene	17	17	100	1.2	196,000	EB27	627	5,939,394	EB27	8	7	47	41
OTHER SVOCs (ug/kg)													
2,4-Dimethylphenol	2	1	50	316	316	EB13	–	–	–	1	1	50	50
2-Methylphenol	2	0	0	<18	<48	–	–	–	–	0	0	0	0
4-Methylphenol	2	1	50	108	108	EB13	–	–	–	0	0	0	0
Pentachlorophenol	2	0	0	<36	<241	–	–	–	–	0	0	0	0
Phenol	2	0	0	<18	<48	–	–	–	–	0	0	0	0
Dibenzofuran	2	2	100	407	28,900	EB13	2,627,273	2,627,273	EB13	2	2	100	100
2-Chloronaphthalene	15	0	0	<4.1	<339	–	–	–	–	–	–	–	–
Carbazole	15	8	53	19	15,200	EB113	–	–	–	–	–	–	–
1-Methylnaphthalene	17	17	100	1.2	118,000	EB27	–	–	–	–	–	–	–
Retene	15	15	100	12	83,300	EB113	–	–	–	–	–	–	–
PCBs (ug/kg)													
Total PCBs	2	0	0	<6.0	<6.5	–	–	–	–	0	0	0	0

Table 2-6—Summary Statistics for Shallow Subsurface (4 to 8 feet bgs) Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations: Dry-Weight Minimum	Dry-Weight Maximum	Dry-Weight Location of Maximum	TOC-Normalized Minimum	TOC-Normalized Maximum	TOC-Normalized Location of Maximum	# of Stations Exceeding Screening Criteria: SQS/LAET[b]	CSL/2LAET[b]	Frequency of Exceedance of Screening Criteria (%)[a]: SQS/LAET	CSL/2LAET
INORGANICS (mg/kg)													
Arsenic	2	1	50	5.3	5.3	EB13	–	–	–	0	0	0	0
Cadmium	2	0	0	<0.15	<0.15	–	–	–	–	0	0	0	0
Chromium	2	2	100	15	16	EB13	–	–	–	0	0	0	0
Copper	2	2	100	9.2	16	EB13	–	–	–	0	0	0	0
Lead	2	2	100	3.5	11	EB13	–	–	–	0	0	0	0
Mercury	2	2	100	0.03	0.24	EB41	–	–	–	0	0	0	0
Nickel	2	2	100	9.0	13	EB13	–	–	–	0	0	0	0
Zinc	2	2	100	22	34	EB13	–	–	–	0	0	0	0

–: Not applicable: Constituent not detected, screening criteria based on dry-weight data or not available, or TOC content outside range for normalization.

<: Not detected at dry-weight detection limit shown.

[a]Frequencies based on total number of stations analyzed.

[b]The nonionic/nonpolar organic chemical data for several core intervals were compared with AETs based on TOC content outside the range determined to be appropriate for normalization (see Table F-1 in Appendix F for sample list).

Table 2-7—Summary Statistics for Shallow Subsurface (8 to 12 feet bgs) Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations						# of Stations Exceeding Screening Criteria		Frequency of Exceedance of Screening Criteria (%)[a]	
				Dry-Weight			TOC-Normalized						
				Minimum	Maximum	Location of Maximum	Minimum	Maximum	Location of Maximum	SQS/LAET[b]	CSL/2LAET[b]	SQS/LAET	CSL/2LAET
PAHs (ug/kg)													
Naphthalene	13	11	85	4.0	3,190,000	EB27	588	91,142,857	EB27	4	4	31	31
Acenaphthylene	13	7	54	4.2	33,800	EB27	677	965,714	EB27	2	2	15	15
Acenaphthene	13	10	77	2.1	1,490,000	EB27	339	42,571,429	EB27	6	5	46	38
Fluorene	13	10	77	5.0	1,490,000	EB27	806	42,571,429	EB27	6	5	46	38
Phenanthrene	13	12	92	12	3,750,000	EB27	1,750	107,142,857	EB27	6	3	46	23
Anthracene	13	13	100	1.5	406,000	EB27	291	11,600,000	EB27	3	2	23	15
Total LPAH	13	13	100	1.6	10,359,800	EB27	291	295,994,286	EB27	6	4	46	31
Fluoranthene	13	12	92	12	1,530,000	EB27	1,824	43,714,286	EB27	4	4	31	31
Pyrene	13	13	100	5.0	933,000	EB27	909	26,657,143	EB27	3	2	23	15
Benzo(a)anthracene	13	9	69	4.7	221,000	EB27	2,661	6,314,286	EB27	3	2	23	15
Chrysene	13	9	69	4.0	201,000	EB27	588	5,742,857	EB27	3	2	23	15
Total Benzofluoranthenes	13	9	69	20	147,900	EB27	4,339	4,225,714	EB27	2	2	15	15
Benzo(a)pyrene	13	8	62	15	61,700	EB27	2,484	1,762,857	EB27	2	2	15	15
Indeno(1,2,3-cd)pyrene	13	9	69	2.7	17,700	EB27	397	505,714	EB27	2	2	15	15
Dibenz(a,h)anthracene	13	6	46	2.8	6,210	EB27	500	177,429	EB27	2	2	15	15
Benzo(g,h,i)perylene	13	9	69	2.9	14,400	EB27	426	411,429	EB27	2	1	15	8
Total HPAH	13	13	100	5.0	3,132,910	EB27	909	89,511,714	EB27	3	2	23	15
2-Methylnaphthalene	13	13	100	1.8	1,570,000	EB27	418	44,857,143	EB27	4	4	31	31
OTHER SVOCs (ug/kg)													
2,4-Dimethylphenol	2	0	0	<9.1	<54	--	--	--	--	0	0	0	0
2-Methylphenol	2	0	0	<9.1	<54	--	--	--	--	0	0	0	0
4-Methylphenol	2	0	0	<9.1	<54	--	--	--	--	0	0	0	0
Pentachlorophenol	2	0	0	<18	<109	--	--	--	--	0	0	0	0
Phenol	2	0	0	<9.1	<54	--	--	--	--	0	0	0	0
Dibenzofuran	2	2	100	27	22,900	EB13	3,013,158	91,142,857	EB13	1	1	50	50
2-Chloronaphthalene	9	0	0	<5.2	<263	--	--	--	--	--	--	--	--
Carbazole	9	5	56	26	95,400	EB27	--	--	--	--	--	--	--
1-Methylnaphthalene	11	11	100	1.6	897,000	EB27	--	--	--	--	--	--	--
Retene	9	9	100	26	5,380	EB12	--	--	--	--	--	--	--
PCBs (ug/kg)													
Total PCBs	2	0	0	<6.0	<9.0	--	--	--	--	0	0	0	0

Table 2-7—Summary Statistics for Shallow Subsurface (8 to 12 feet bgs) Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations						# of Stations Exceeding Screening Criteria		Frequency of Exceedance of Screening Criteria (%)[a]	
				Dry-Weight			TOC-Normalized						
				Minimum	Maximum	Location of Maximum	Minimum	Maximum	Location of Maximum	SQS/LAET[b]	CSL/2LAET[b]	SQS/LAET	CSL/2LAET
INORGANICS (mg/kg)													
Arsenic	2	1	50	5.3	5.3	EB41	--	--	--	0	0	0	0
Cadmium	2	0	0	<0.15	<0.15	EB13	--	--	--	0	0	0	0
Chromium	2	2	100	10	19	EB13	--	--	--	0	0	0	0
Copper	2	2	100	7.6	17	EB13	--	--	--	0	0	0	0
Lead	2	2	100	4.9	5.5	EB13	--	--	--	0	0	0	0
Mercury	2	1	50	0.03	0.03	EB13	--	--	--	0	0	0	0
Nickel	2	2	100	8.8	13	EB13	--	--	--	0	0	0	0
Zinc	2	2	100	20	31	EB13	--	--	--	0	0	0	0

--: Not applicable: Constituent not detected, screening criteria based on dry-weight data or not available, or TOC content outside range for normalization.

<: Not detected at dry-weight detection limit shown.

[a]Frequencies based on total number of stations analyzed.

[b]The nonionic/nonpolar organic chemical data for several core intervals were compared with AETs based on TOC content outside the range determined to be appropriate for normalization (see Table F-1 in Appendix F for sample list).

Table 2-8—Summary Statistics for Shallow Subsurface (12 to 16 feet bgs) Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations						# of Stations Exceeding Screening Criteria		Frequency of Exceedance of Screening Criteria (%)[a]	
				Dry-Weight			TOC-Normalized						
				Minimum	Maximum	Location of Maximum	Minimum	Maximum	Location of Maximum	SQS/LAET[b]	CSL/2LAET[b]	SQS/LAET	CSL/2LAET
PAHs (ug/kg)													
Naphthalene	10	7	70	6.7	79,800	EB27	933	8,142,857	EB27	2	2	20	20
Acenaphthylene	10	2	20	24	825	EB27	4,286	84,184	EB27	1	1	10	10
Acenaphthene	10	6	60	6.5	41,000	EB27	1,032	4,183,673	EB27	2	2	20	20
Fluorene	10	6	60	7.4	40,500	EB27	1,190	4,132,653	EB27	2	2	20	20
Phenanthrene	10	9	90	7.7	97,100	EB27	1,069	9,908,163	EB27	2	2	20	20
Anthracene	10	8	80	1.9	13,500	EB27	271	1,377,551	EB27	1	1	10	10
Total LPAH	10	9	90	7.7	272,725	EB27	1,069	27,829,082	EB27	2	2	20	20
Fluoranthene	10	8	80	9.1	53,100	EB27	1,300	5,418,367	EB27	2	1	20	10
Pyrene	10	9	90	4.2	32,300	EB27	1,186	3,295,918	EB27	1	1	10	10
Benzo(a)anthracene	10	4	40	4.9	8,690	EB27	9,492	886,735	EB27	1	1	10	10
Chrysene	10	7	70	2.6	8,460	EB27	371	863,265	EB27	1	1	10	10
Total Benzofluoranthenes	10	6	60	8.8	5,630	EB27	1,467	574,490	EB27	1	1	10	10
Benzo(a)pyrene	10	3	30	31	2,350	EB27	4,873	239,796	EB27	1	1	10	10
Indeno(1,2,3-cd)pyrene	10	4	40	2.9	723	EB27	483	73,776	EB27	1	0	10	0
Dibenz(a,h)anthracene	10	1	10	225	225	EB27	22,959	22,959	EB27	1	0	10	0
Benzo(g,h,i)perylene	10	4	40	3.0	571	EB27	500	58,265	EB27	1	0	10	0
Total HPAH	10	9	90	4.2	112,049	EB27	2,857	11,433,571	EB27	1	1	10	10
2-Methylnaphthalene	10	8	80	1.4	36,200	EB27	200	3,693,878	EB27	2	2	20	20
OTHER SVOCs (ug/kg)													
2,4-Dimethylphenol	2	0	0	<11	<19	--	--	--	--	0	0	0	0
2-Methylphenol	2	0	0	<11	<19	--	--	--	--	0	0	0	0
4-Methylphenol	2	0	0	<11	<19	--	--	--	--	0	0	0	0
Pentachlorophenol	2	0	0	<23	<38	--	--	--	--	0	0	0	0
Phenol	2	0	0	<11	<19	--	--	--	--	0	0	0	0
Dibenzofuran	2	1	50	1,030	1,030	EB13	183,929	183,929	EB13	1	1	50	50
2-Chloronaphthalene	6	0	0	<4.6	<21	--	--	--	--	--	--	--	--
Carbazole	6	2	33	0.003	2,690	EB27	--	--	--	--	--	--	--
1-Methylnaphthalene	8	7	88	1.4	21,400	EB27	--	--	--	--	--	--	--
Retene	6	6	100	20	265	EB27	--	--	--	--	--	--	--
PCBs (ug/kg)													
Total PCBs	2	0	0	<4.8	<11.5	--	--	--	--	0	0	0	0

Table 2-8—Summary Statistics for Shallow Subsurface (12 to 16 feet bgs) Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations: Dry-Weight Minimum	Dry-Weight Maximum	Dry-Weight Location of Maximum	TOC-Normalized Minimum	TOC-Normalized Maximum	TOC-Normalized Location of Maximum	# of Stations Exceeding Screening Criteria: SQS/LAET[b]	CSL/2LAET[b]	Frequency of Exceedance of Screening Criteria (%)[a]: SQS/LAET	CSL/2LAET
INORGANICS (mg/kg)													
Arsenic	2	2	100	5.2	6.3	EB41	--	--	--	0	0	0	0
Cadmium	2	0	0	<0.15	<0.15	--	--	--	--	0	0	0	0
Chromium	2	2	100	16	21	EB41	--	--	--	0	0	0	0
Copper	2	2	100	17	18	EB13	--	--	--	0	0	0	0
Lead	2	2	100	4.9	5.9	EB13	--	--	--	0	0	0	0
Mercury	2	2	100	0.03	0.04	EB41	--	--	--	0	0	0	0
Nickel	2	2	100	13	13	EB13	--	--	--	0	0	0	0
Zinc	2	2	100	32	33	EB13	--	--	--	0	0	0	0

-- Not applicable: Constituent not detected, screening criteria based on dry-weight data or not available, or TOC content outside range for normalization.

< Not detected at dry-weight detection limit shown.

[a]Frequencies based on total number of stations analyzed.

[b]The nonionic/nonpolar organic chemical data for several core intervals were compared with AETs based on TOC content outside the range determined to be appropriate for normalization (see Table F-1 in Appendix F for sample list).

Table 2-9—Summary Statistics for Shallow Subsurface (16 to 20 feet bgs) Sediment COCs

				Detected Concentrations						# of Stations Exceeding Screening Criteria		Frequency of Exceedance of Screening Criteria (%)[a]	
				Dry-Weight			TOC-Normalized						
Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Minimum	Maximum	Location of Maximum	Minimum	Maximum	Location of Maximum	SQS/LAET[b]	CSL/2LAET[b]	SQS/LAET	CSL/2LAET
PAHs (ug/kg)													
Naphthalene	8	5	63	7.1	1,920	EB27	37,778	37,778	EB13	0	0	0	0
Acenaphthylene	8	1	13	18	18	EB27	--	--	--	0	0	0	0
Acenaphthene	8	6	75	4.3	1,450	EB27	717	20,952	EB13	2	1	25	13
Fluorene	8	5	63	6.6	1,440	EB27	20,317	20,317	EB13	1	1	13	13
Phenanthrene	8	7	88	4.2	3,560	EB27	3,417	48,889	EB13	1	0	13	0
Anthracene	8	7	88	1.2	643	EB27	1,600	7,397	EB13	0	0	0	0
Total LPAH	8	8	100	1.2	9,031	EB27	5,733	135,333	EB13	1	0	13	0
Fluoranthene	8	4	50	23	2,440	EB27	20,952	20,952	EB13	1	0	13	0
Pyrene	8	6	75	4.0	1,480	EB27	1,367	12,508	EB13	0	0	0	0
Benzo(a)anthracene	8	2	25	22	368	EB27	3,540	3,540	EB13	0	0	0	0
Chrysene	8	2	25	24	386	EB27	3,746	3,746	EB13	0	0	0	0
Total Benzofluoranthenes	8	3	38	3.6	238	EB27	4,397	4,397	EB13	0	0	0	0
Benzo(a)pyrene	8	1	13	91	91	EB27	--	--	--	0	0	0	0
Indeno(1,2,3-cd)pyrene	8	1	13	25	25	EB27	--	--	--	0	0	0	0
Dibenz(a,h)anthracene	8	1	13	9.8	9.8	EB27	--	--	--	0	0	0	0
Benzo(g,h,i)perylene	8	1	13	21	21	EB27	--	--	--	0	0	0	0
Total HPAH	8	6	75	4.0	5,058	EB27	1,367	45,143	EB13	0	0	0	0
2-Methylnaphthalene	8	6	75	2.2	419	EB27	20,952	20,952	EB13	0	0	0	0
OTHER SVOCs (ug/kg)													
2,4-Dimethylphenol	2	0	0	<11	<11	--	--	--	--	0	0	0	0
2-Methylphenol	2	0	0	<11	<11	--	--	--	--	0	0	0	0
4-Methylphenol	2	0	0	<11	<11	--	--	--	--	0	0	0	0
Pentachlorophenol	2	0	0	<22	<22	--	--	--	--	0	0	0	0
Phenol	2	0	0	<11	<11	--	--	--	--	0	0	0	0
Dibenzofuran	2	1	50	99	99	EB13	15,778	15,778	EB13	1	0	50	0
2-Chloronaphthalene	4	0	0	<4.6	<5.4	--	--	--	--	--	--	--	--
Carbazole	4	1	25	214	214	EB27	--	--	--	--	--	--	--
1-Methylnaphthalene	6	5	83	1.7	304	EB27	--	--	--	--	--	--	--
Retene	4	4	100	34	44	EB32	--	--	--	--	--	--	--
PCBs (ug/kg)													
Total PCBs	2	0	0	<11	<11	--	--	--	--	0	0	0	0

Table 2-9—Summary Statistics for Shallow Subsurface (16 to 20 feet bgs) Sediment COCs

Constituent	# of Stations Analyzed	# of Detected Values	Frequency of Detection (%)	Detected Concentrations: Dry-Weight Minimum	Dry-Weight Maximum	Dry-Weight Location of Maximum	TOC-Normalized Minimum	TOC-Normalized Maximum	TOC-Normalized Location of Maximum	# of Stations Exceeding Screening Criteria: SQS/LAET[b]	CSL/2LAET[b]	Frequency of Exceedance of Screening Criteria (%)[a]: SQS/LAET	CSL/2LAET
INORGANICS (mg/kg)													
Arsenic	2	1	50	7.2	7.2	EB41	--	--	--	0	0	0	0
Cadmium	2	0	0	<0.15	<0.15	--	--	--	--	0	0	0	0
Chromium	2	2	100	18	18	EB13	--	--	--	0	0	0	0
Copper	2	2	100	17	20	EB41	--	--	--	0	0	0	0
Lead	2	2	100	3.0	4.8	EB13	--	--	--	0	0	0	0
Mercury	2	2	100	0.02	0.17	EB41	--	--	--	0	0	0	0
Nickel	2	2	100	14	15	EB41	--	--	--	0	0	0	0
Zinc	2	2	100	32	35	EB41	--	--	--	0	0	0	0

--: Not applicable: Constituent not detected, screening criteria based on dry-weight data or not available, or TOC content outside range for normalization.
<: Not detected at dry-weight detection limit shown.
[a]Frequencies based on total number of stations analyzed.
[b]The nonionic/nonpolar organic chemical data for several core intervals were compared with AETs based on TOC content outside the range determined to be appropriate for normalization (see Table F-1 in Appendix F for sample list).

Table 2-10—Items To Be Considered—PSR Site Sediment Remediation

Federal, State, and Local Criteria, Advisories and Procedures	Comments
Guidelines developed by the Elliott Bay/Duwamish Restoration Panel	Guidelines for habitat restoration
Puget Sound Water Quality Management Plan	Defines objectives for standards regarding the confined disposal of contaminated sediment
Standards for Confined Disposal of Contaminated Sediments, Washington Department of Ecology (January 1990)	Guidelines for assessing the suitability of dredged material for unconfined disposal relevant to cap material specifications
Federal and State Water Quality Guidance Documents	Contains policy and technical data reviewed and/or used in the development of state sediment management standards
Area of Contamination Interprogram Policy, developed by Washington Department of Ecology	Guidelines for the management of dredged sediment meeting the criteria as a state dangerous waste
Sediment Cleanup Standards Users Manual, Washington State Department of Ecology (December, 1991)	Guidance for implementing the sediment cleanup decision process for contaminated sediments in Washington State
Sediment Source Control Standards Users Manual, Washington State Department of Ecology (June, 1993)	Guidance for implementing the Sediment Source Control Standards
Local Shoreline Master Program	Guidelines for managed development of shorelines to preserve natural resources while protecting public access and navigation.
Sediment Quality Criteria for the Protection of Human Health	Proposes draft sediment quality standards based on risks to humans

Table 3-1—Potential Thin-Layer Capping Areas

Station	SQS Exceedance Factor	Area (sq. ft.)
EB 023	1.44	17,441
EB 035	1.28	42,349
EB 056	1.76	59,935
EB 057	1.08	85,626
EB 060	1.9	46,088
EB 091	1.50	52,804
EB 095	1.34	66,088
EB 101	1.36	47,596
EB 117	1.57	63,055
EB 124	1.11	89,074
EB 127	1.34	102,665
EB 128	1.35	129,554
EB 136	1.48	87,126
EB 137	1.51	122,051
EB 144	1.42	71,270
Total		1,082,722

Table 3-2—Technology Screening Summary

General Response Action	Technology Type	Screening Comments	Retained for Alternative Development
Containment	Sand/Silt Capping	Capping can protect the environment and human health. A cap over the contaminated sediments could be constructed without extreme difficulties. Some difficulty may be experienced in obtaining a readily available supply of clean cap material. Capping will be evaluated to achieve both SQS (~$5 million) and CSL (~$8 million) standards.	Yes
Removal	Hydraulic Dredging	Hydraulic dredging results in minimal resuspension of contaminated sediment. Hydraulic dredging can attain depths of 150 feet. Hydraulic dredges typically generate significant quantities of dredge water that requires handling and treatment. However, special hydraulic dredges can remove sediment at 50 to 60% solids.	Yes
		Dredging all sediments exceeding CSLs may be technically feasible. The area associated with CSL exceedances occurs at depths <200 feet MLLW and generates a volume of about 500,000 cubic yards. Cost of removal and disposal are roughly estimated to be from $15 to $30 million depending on the disposal option.	Yes
		Dredging all sediment exceeding SQS standards would be technically difficult due to dredge depth limitations (approximately -200 feet). In addition it would be extremely expensive (about $60 million) and no local disposal sites are available that could handle approximately 1 million cubic yards. Therefore, dredging all sediment that exceeds SQS standards is not considered further.	No
	Mechanical Dredging	Mechanical dredges can attain depths of over 200 feet. Mechanical dredges remove sediment at near *in situ* densities with a minimum of entrained water. Removal rates are slower compared to hydraulic dredging. High resuspension rates may be experienced.	Yes
		Dredging all sediments exceeding CSLs may be technically feasible. The area associated with CSL exceedances occurs at depths <200 feet MLLW and generates a volume of about 500,000 cubic yards. Cost of removal and disposal are roughly estimated at $30 million.	Yes

Table 3-2—Technology Screening Summary

General Response Action	Technology Type	Screening Comments	Retained for Alternative Development
Removal	Mechanical Dredging	Dredging all sediment exceeding SQS standards would be technically difficult due to dredge depth limitations (about -200 feet). In addition it would be extremely expensive and no local disposal sites are available that could handle this volume of material. Therefore, dredging all sediment that exceeds SQS standards is not considered further.	No
Disposal Following Removal	Nearshore Site	A potential nearshore site could be constructed east of the PSR pier extending over to the second Lockheed pier. This site would have significant capacity (approximately 600,000 C.Y.) for disposing PSR sediments. This site is relatively deep and flat making it acceptable for nearshore sediment disposal.	Yes
	Confined Aquatic Site	This type of disposal site is effective in disposing of contaminated sediments. This type of disposal has been retained assuming sites are available.	Yes
	Upland Site	Upland sites are available. An area ranging from 11 to 22 acres in size would be needed to dispose of the sediments. This quantity of space is readily available in the surrounding urban area.	Yes
	Landfill	Disposal at an existing landfill would be prohibitively expensive ($59,000,000 to $120,000,000) and would require stabilization prior to disposal.	No
Treatment Following Removal	Thermal	Processing rates vary from 100 to 720 tons per 24 hour day. Treatment could take up to 4 years at an absolute minimum. Large upland areas would be needed for treatment process setup. Dredging costs would be prohibitively expensive unless an upland stockpile of enormous proportions was built. Costs would be high ($176,000,000 to $363,000,000), with elevated short-term risks.	No
	Soil Washing	Processing rates vary from 20 to 720 tons per 24 day. Treatment could take up to 4 years. Large upland areas would be needed for treatment process setup. Dredging costs would be prohibitively expensive unless an upland stockpile of enormous proportions was built. Costs would be high ($105,000,000 to $217,000,000), with elevated short-term risks.	No

Table 3-2—Technology Screening Summary

General Response Action	Technology Type	Screening Comments	Retained for Alternative Development
Treatment Following Removal	Solvent Extraction	Processing rates vary from 20 to 360 tons per 24 hour day. Treatment could take up to 8 years. Large upland areas would be needed for treatment process setup. Dredging costs would be prohibitively expensive unless an upland stockpile of enormous proportions was built. Costs would be high ($141,000,000 to $290,000,000), with elevated short-term risks.	No

Table 4-1—Comparison of Dredge Equipment

Dredge Type	Depth Range (feet)	Production Rate per 24-hour day	% Solids by Weight	Resuspension Potential	Material Transport Method	Volume Increase at Disposal Point
Closed Clamshell	0 – 200	500 – 3,500 CY	> 60%	Moderate to high	Barge	15 – 25%
Cutterhead Suction	3 – 90	3,000 – 15,000 CY	10 to 20%	Low to moderate	Pipeline	15 – 25%
High Energy Vortex (Eddy Pump™)	3 – 200	4,000 – 18,000 CY	50 to 60%	Low	Pipeline	15 – 25%
Limited Access Hydraulic	0 – 60	500 – 1,500 CY	10 to 20%	Low to moderate	Pipeline	15- 25%

CY = Cubic Yards

Table 4-2—Estimated Schedule of Available Capping Material

Source Location	Percent Sand	1999	2000	2001	2002	2003	2004	2005
Duwamish River: Upstream of Settling Basin	70-90%	40,000 CY	0	40,000 CY	0	40,000 CY	0	40,000 CY
Duwamish River: Lower Reach	<50%	100,000 CY	0	100,000 CY	0	100,000 CY	0	100,000 CY
Snohomish River: Upper Reach	90%	0	0	0	240,000 CY	0	0	240,000 CY
Snohomish River: Lower Reach	70%	0	0	240,000 CY	0	240,000 CY	0	240,000 CY
Everett Home Port	70% (est.)	0	150,000 CY	0	0	0	0	0
Annual Volume of Sandy Material (excludes lower Duwamish River)		40,000 CY	150,000 CY	280,000 CY	240,000 CY	280,000 CY	0	320,000 CY
Annual Total Volume		140,000 CY	150,000 CY	380,000 CY	240,000 CY	380,000 CY	0	420,000 CY
Cumulative Volume of Sandy Material (excludes lower Duwamish River		40,000 CY	190,000 CY	470,000 CY	710,000 CY	890,000 CY	890,000 CY	1,210,000 CY
Cumulative Total Volume		140,000 CY	290,000 CY	670,000 CY	910,000 CY	1,290,000 CY	1,290,000 CY	1,710,000 CY

CY = Cubic Yard.

Dredge Material from Upper Snohomish River may not be available until 2002 due to existing commitments. Available quantities are variable depending on runoff and dredging requirements.

Table 4-3—Short-Term Monitoring

Area	Sample Location	No. of Samples	Frequency	Analytes
Point of Dredging	3 equidistant stations around dredge location	3 @ each location vertically spaced throughout the water column	1 round, 3 times a day for the first 5 days. 2 rounds per week thereafter	Turbidity, dissolved oxygen and PAHs.
Nearfield	2 stations, one upcurrent and one down current	3 @ each location vertically spaced throughout the water column	1 round, 3 times a day for the first 5 days. 2 rounds per week thereafter	Turbidity, dissolved oxygen and PAHs.
Farfield	1 upgradient background station	3 @ each location vertically spaced throughout the water column	1 round, 3 times a day for the first 5 days. 2 rounds per week thereafter	Turbidity, dissolved oxygen and PAHs.

Table 4-4—Post-Remediation Dredge Monitoring

Location	No. of Samples	Frequency	Analytes
Dredged Area	1 per 2 acres dredged	Once after an appropriate size area has been dredged	PAHs and Bioassays

Table 4-5—Long-Term Dredged Area Monitoring

Location	No. of Samples	Frequency	Analytes
Dredged Area	1 station per 3 acres dredged. 2 samples from each station (cap surface and bottom 1 foot of cap)	1 round 1 year after dredginhg has been completed. 1 round every 5 years thereafter	PAHs

Table 4-6—Long-Term Capped Area Monitoring

Location	No. of Samples	Frequency	Analytes
Capped Area	1 per 6 acres dredged	1 round every other year	PAHs

Table 4-7—Comparison of Fill Area Contamination vs. Total Site Contamination for SQS Criteria

	Mass (lbs)	Volume (CY)	Area (SY)
Total Site	1,167,000	967,000	455,600
Fill Area	1,130,000	378,000	114,000

Table 4-8—Comparison of Fill Area Contamination vs. Total Site Contamination for CSL Criteria

	Mass (lbs)	Volume (CY)	Area (SY)
Total Site	920,000	471,000	227,800
Fill Area	903,000	326,000	114,000

Table 4-9—Alternative Summary

Alternative	Cleanup Goal	Cap Material Required (cubic yards)	Capping Area (square yards)	Dredged Volume (cubic yards)	Disposal Capacity Needed* (cubic yards)
Alternative 1 No Action	Not Applicable	0	0	0	0
Alternative 2 Dredging	CSL	Offshore: 71,000 Shoreline: 16,000 GDZ: 20,000 **Total: 107,000**	Offshore: 34,000 Shoreline: 16,000 GDZ: 20,000 **Total: 70,000**	Offshore: 313,000 CMS: 9000 GDZ: 50,000 **Total: 372,000**	428,000
Alternative 3a Capping	SQS	Offshore: 740,000 Shoreline: 18,000 GDZ: 20,000 **Total: 778,000**	Offshore: 426,000 Shoreline: 18,000 GDZ: 20,000 **Total: 464,000**	Offshore: 0 CMS: 3,500 GDZ: 0 **Total: 3,500**	0 (disposed offshore within MSC and capped)
Alternative 3b Capping	CSL	Offshore: 328,000 Shoreline: 15,000 GDZ: 20,000 **Total: 363,000**	Offshore: 193,000 Shoreline: 15,000 GDZ: 20,000 **Total: 228,000**	Offshore: 0 CMS: 3,500 GDZ: 0 **Total: 3,500**	0 (disposed offshore within MSU and capped)
Alternative 4a Fill Area Removal and Capping	SQS	Offshore: 531,000 Shoreline: 18,000 GDZ: 20,000 **Total: 569,000**	Offshore: 318,000 Shoreline: 18,000 GDZ: 20,000 **Total: 356,000**	Offshore: 328,000 CMS: 3,500 GDZ: 50,000 **Total: 381,500**	439,000
Alternative 4b Fill Area Removal and Capping	CSL	Offshore: 119,000 Shoreline: 15,000 GDZ: 20,000 **Total: 154,000**	Offshore: 82,000 Shoreline: 15,000 GDZ: 20,000 **Total: 117,000**	Offshore: 220,000 CMS: 3,500 GDZ: 50,000 **Total: 273,500**	315,000

Notes
GDZ: Groundwater Discharge Zone
CMS: Crowley Marine Services
See **Figure 3-1 or 3-2** for depiction of shoreline area
* 15% bulking factor

Table 4-10—Evaluation of Potential Confined Aquatic Disposal (CAD) Sites

Evaluation Criteria	Site 1*	Site 2*
Distance from PSR (miles)	0.5	3
Depth below MLLW (feet)	155 to 200	80 to 120
Area (acres)	40	43
Capacity (cubic yards)[1]	590,000	730,000
Native slope	0 to 6%	3 to 6%
Other considerations	• Site borders the Elliott Bay PSDDA site	• Site is adjacent to Elliott Bay Marina and is subjected to extensive boat activity • Site is exposed to southerly fetch and storm conditions

[1] CAD site capacity assumes a 15-foot maximum fill thickness and 10H to 1V side slopes.
* (see Figure 4-12)

Table 4-11—Potential Nearshore Disposal Sites

Site	Site Retained for Further Evaluation?	Justification
PSR	Yes	Due to steep bottom slopes, only the eastern portion of the site is suitable for berm construction.
Lockheed	Yes	Site is part of the Port of Seattle's Southwest Harbor Project and may be available for a multi-user nearshore disposal site.
Terminal 91	No	Port owns this property and is not planning to use this site for disposal purposes.
Pier 89 to Pier 71	No	Adjacent to area with considerable ship traffic and is near a highly used public park.
Pier 70 to Pier 50	No	High level of boat traffic. Site includes most of the retail businesses and tourist attractions that comprise downtown waterfront.
Pier 48	No	Site currently permitted for passenger ferry use, and displacement of this use is difficult to accommodate.
Terminal 46 to Pier 36	No	Impoundment at this site would impede ship traffic
Pier 36	No	Current use of site by U.S. Coast Guard for berthing and maintenance precludes its use for sediment disposal.
Pier 27	No	Property is owned by the Port of Seattle and will be used as a disposal site for another project. No additional capacity is available.
Pier 2	No	Pier 2 is an active barge terminal currently operated by Crowley Marine Services. Steeper slopes (15 to 18 percent) in this area would make berm construction difficult.

Reference: SouthWest Harbor Island Environmental Impact Statement.

Table 4-12—Nearshore Disposal Site Information

Item	Configuration A	Configuration B
Rock Berm with Sand Core		
Disposal capacity	480,000 CY	350,000 CY
Disposal area (including berm land habitat)	84,700 SY 17.5 acres	70,600 SY 14.5 acres
Berm length	2,100 feet	1,900 feet
Riprap volume	132,700 CY	124,250 CY
Sand Core volume	88,600 CY	83,000 CY
Habitat Sand Volume	73,000 CY	61,000 CY
Additional Information for Configuration A and B		
Berm height (range in feet)		20 to 50
Berm width at base (range in feet including habitat)		150 to 230
Berm width at top (feet)		10
Berm depth (range in feet below MLLW)		-6 to -40

CY = Cubic yards.
SY = Square yards.

Table 4-13—Potential Upland Disposal Sites

Site Number	Site	Site Retained for Further Evaluation?	Justification
1	Adjacent to Van Doren's Landing Park	Yes	Large amount of undeveloped vacant land (152 acres) owned by City of Kent.
2	Corner of S. 212th and SR 181	No	Property is owned by Boeing.
3	S. 180th between SR 181 and Hwy 167	No	Currently developed with commercial warehouses. Upon visual inspection, does not appear to be a viable disposal site.
4	South of former Long Acres racetrack	Yes	Approximately 73 acres of undeveloped land owned by city of Renton. Bordered by Burlington Northern industrial parks.
5	Former Longacres racetrack.	No	Currently owned and in the process of development by Boeing.
6	Coalfield County Park	No	Park consists of ballfields, playgrounds, and a wooded area located west of the parks fenceline. Park is bordered by private residences.
7	Maplewood Heights Park	No	Park is surrounded by private residences and consists of dense forest with walking trails throughout the property.
8, 9	Property near Lake Desire and Otter Lake	No	Property adjacent to residential lake development.
10	Property surrounding Lake Youngs	No	Property surrounds Lake Youngs, a City of Seattle watershed.
11	Shoreline property west of I-405	No	Property is along Lake Washington shoreline and is too valuable to be further considered.
12	Golf Course in Seattle	No	Site was a landfill and is currently a golf course.

Table 5-1—CAD Disposal Costs

Alternative	Disposal Volume (cubic yards) [a]	Cost [b] ($)
Alternative 2—Dredging to CSLs	428,000	7,704,000
Alternative 4a—Fill Removal to SQS and Capping	439,000	7,902,000
Alternative 4b—Fill Removal to CSL and Capping	315,000	5,670,000

[a] assumes a bulking factor of 15% (based on use of vortex-type dredge).
[b] disposal cost is $18/cubic yard (see Appendix D for further cost details).

Table 5-2—Nearshore Disposal Costs

Alternative	Disposal Volume (cubic yards) [a]	Cost [b] ($)
Alternative 2—Dredging to CSLs	428,000	11,128,000
Alternative 4a—Fill Removal to SQS and Capping	439,000	11,414,000
Alternative 4b—Fill Removal to CSL and Capping	315,000	8,190,000

[a] assumes a bulking factor of 15% (based on use of vortex-type dredge).
[b] disposal cost is $26/cubic yard (see Appendix D for further cost details).

Table 5-3—Upland Disposal Costs

Alternative	Disposal Volume (cubic yards) [a]	Cost [b] ($)
Alternative 2— Dredging to CSLs	428,000	19,260,000
Alternative 4a—Fill Removal to SQS and Capping	439,000	19,755,000
Alternative 4b—Fill Removal to CSL and Capping	315,000	14,175,000

[a] assumes a bulking factor of 15% (based on use of vortex-type dredge).
[b] disposal cost is $45/cubic yard (see Appendix D for further cost details).

Table 5-4—Alternative Cost Summary

Alternative	Capital Cost ($)	Long-term Monitoring/ Maintenance Cost ($)	Total Cost ($)
Alternative 1—No Action	0	0	0
Alternative 2—Dredging to CSLs	4,661,000	2,172,000	6,833,000
Alternative 3—Capping			
3a—Capping to SQS	9,500,000	5,350,000	14,851,000
3b—Capping to CSLs	4,846,000	2,753,000	7,599,000
Alternative 4—Fill Removal and Capping			
4a—Fill Removal to SQS	9,880,000	4,483,000	14,363,000
4b—Fill removal to CSLs	4,442,000	1,710,000	6,152,000

Table 5-5—Disposal Costs

Alternative	Disposal Volume [1] (cubic yards)	Disposal Option		
		CAD Disposal Cost [2] ($)	Nearshore Disposal Cost [3] ($)	Upland Disposal Cost [4] ($)
Alternative 2—Dredging to CSLs	428,000	7,704,000	11,128,000	19,260,000
Alternative 4—Fill Removal and Capping				
4a—Removal to SQS	439,000	7,902,000	11,414,000	19,755,000
4b—Removal to CSLs	315,000	5,670,000	8,190,000	14,175,000

[1] Assumes a bulking factor of 15% (based on use of vortex-type dredge).
[2] CAD costs based on a unit cost of $18 / cubic yard.*
[3] Nearshore costs based on a unit cost of $26 / cubic yard. Includes habitat mitigation.*
[4] Upland costs based on a unit cost of $45 / cubic yard.*
*(see Appendix D for further cost details)

Table 5-6—Alternative Ranking

Alternative	Overall Protection	ARARs	Reduction in Toxicity, Mobility and Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost	Total	Rank
2. Dredge to CSL	1	3	3	2	5	5	2	21	3
3. Capping									
a. SQS	5	3	3	3	1	1	4	20	2
b. CSL	3	3	3	5	2	3	5	24	5
4. Fill Area Removal									
a. SQS	4	3	3	1	3	2	1	17	1
b. CSL	2	3	3	4	4	4	3	23	4

5 = highest rank (most protective, effective, implementable, least cost, etc.)
1 = lowest rank
See Appendix G for details on scoring.

Table 5-7—Disposal Option Ranking

Alternative	Overall Protection	ARARs	Toxicity, Mobility and Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost	Total	Rank
Upland	2	2.5	2	2	3	3	1	15.5	1.5
Nearshore	2	2.5	2	3	2	2	2	15.5	1.5
CAD	2	1	2	1	1	1	3	11	3

Tied ranks are averaged.

APPENDIX A

RECONTAMINATION EVALUATION

The recontamination analysis evaluates the potential for resuspended solids to contaminate an un-impacted area to a sediment quality above SQS. Dredging results in loss of sediment into the water column which then settles to the bottom in a pattern where the size of the "footprint" depends upon depth. The size of this settlement pattern was estimated based on previous work and modeling performed by the Corps of Engineers. Dredging highly contaminated sediment has less of a tolerance for loss during dredging due to the greater mass of contamination being deposited over the bottom.

This evaluation was performed to determine what volume of dredged sediment, given an assumed loss, would result in recontamination of the depositional area above SQS criteria. If the dredged volume is large, recontamination is less significant. If dredging a small quantity of sediment will contaminate the depositional area, recontamination from dredging is more of a concern.

The methodology used assumed a given concentration of sediment contamination and determined how much (i.e. weight) of this sediment could be dispersed over a clean area such that a 10 centimeter core would not fail SQS criteria when analyzed. Based on this quantity, a total mass of allowable contaminated sediment deposition was calculated over the depositional area. Then assuming a 2 percent dredging loss, the total quantity of dredged sediment that would result in this loss was back-calculated.

The assumptions used were based on previous Corps of Engineers work or dredge performance data. A 500-foot radius of deposition was used based on Corps modeling. The LPAH concentrations used were a worst-case scenario based on sediment data from PSR. The 25 percent sediment loss factor was based on discussions with dredgers, the Corps and literature information.

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WESTON MANAGERS DESIGNERS/CONSULTANTS

CLIENT/SUBJECT PSR FS W.O. NO.

TASK DESCRIPTION Recontamination Analysis TASK NO.

PREPARED BY L. Vanselow DEPT DATE 6/4/98

MATH CHECK BY DEPT DATE

METHOD REV. BY DEPT DATE

APPROVED BY

DEPT DATE

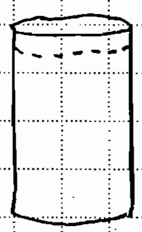
Assumptions: 2% resuspension rate via clamshell dredging

100' deep dredge depth

500' radius for sediment redeposition

LPAH concentration in sediment is 200 ppm

LPAH SQS = 5.2 ppm



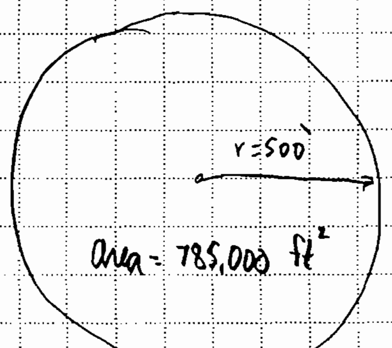
Area $= \pi r^2 = 0.0055\ ft^2$

10 cm long core (4.0")
1" Ø

$Vol = \pi \left(\frac{0.5}{12}\right)^2 \frac{4}{12} = 0.0018\ ft^3$

$0.0018\ ft^3 \times 100 \frac{\#}{ft^3} = 0.18\ \#$

$\frac{5.2}{1\times10^6} = \frac{x}{0.18}$ $x = \frac{9.4\times10^{-7}\ \#\ LPAH}{0.0055\ ft^2} = 0.000171$



Area $= \pi r^2 = 3.14\ (500)^2 = 785{,}000\ ft^2$

$785{,}000\ ft^2 \times 1.71\times10^{-4} = 134\ \#$ LPAH's

WESTON MANAGERS DESIGNERS/CONSULTANTS

CLIENT/SUBJECT ______ W.O. NO. ______

TASK DESCRIPTION ______ TASK NO. ______

PREPARED BY ______ DEPT ______ DATE ______

MATH CHECK BY ______ DEPT ______ DATE ______

METHOD REV. BY ______ DEPT ______ DATE ______

APPROVED BY ______ DEPT ______ DATE ______

$\frac{200}{1\times10^4} = \frac{134}{x}$ $x = 670{,}000$ # SEDIMENT = 6700 ft^3 = 248 cy

@ 2% loss $\frac{248}{0.02}$ = 12,400 cy SEDIMENT DREDGED

∴ DREDGING 12,400 cy OF SEDIMENT @ 200 mg/kg LPAH's could recontaminate an AREA OF 785,000 ft^2 (18 ACRES) TO SQS.

SHEET 1 of 3

CLIENT/SUBJECT PSR FS W.O. NO.

TASK DESCRIPTION CAD Site Analysis TASK NO.

PREPARED BY L. VANSELOW DEPT DATE 6/2/98

MATH CHECK BY DEPT DATE

METHOD REV. BY DEPT DATE

APPROVED BY

DEPT DATE

REF: Analysis of Dredged Material Deposition Patterns, Eric Nelson, et al. ACE, 1992

GIVEN: • Dumping of sediment in 400' of water generated a 2100' radius disposal pattern

• Material consisted of 15% sand, 1% clay, 29% silt, 55% water

• PSR sediment is 30% sand, 3% clay, 20% silt, 47% water

Assumptions • PSR CAD sites are 100' and 200' deep

• Similar current conditions to Everett Home Port

• Similar discharge footprints for PSR

RFW 10-05-003/A-5/85
512-5643

WESTON
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CLIENT/SUBJECT ______ W.O. NO. ______

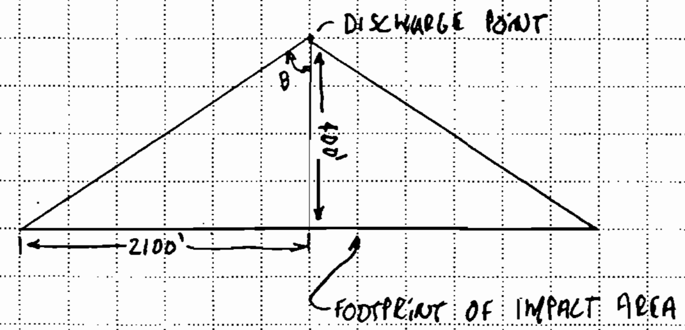
TASK DESCRIPTION ______ TASK NO. ______

PREPARED BY ______ DEPT ______ DATE ______

MATH CHECK BY ______ DEPT ______ DATE ______

METHOD REV. BY ______ DEPT ______ DATE ______

APPROVED BY ______ DEPT ______ DATE ______

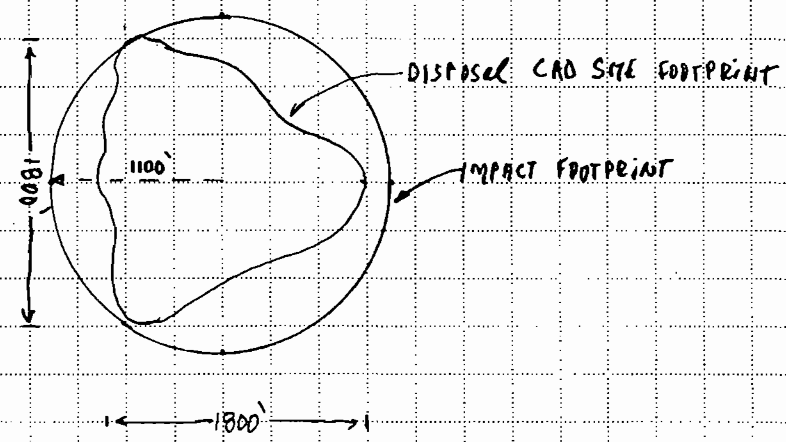


DISCHARGE ∡ $\theta = \text{ATAN}\left(\frac{2100}{400}\right)$ $\theta = \text{ATAN } 5.25$ $\theta = 79°$

FOR A 200' DEEP SITE, IMPACT RADIUS (r) = Tan 79° (200) r = 1100'

FOR A 100' DEEP SITE, r = Tan 79° (100) = 525'

CAD SITE 1
200' DEEP



→ DISPOSAL AT CAD SITE 1 WOULD RESULT IN DISPOSED MATERIAL OUTSIDE TARGET BOUNDARY

WESTON
MANAGERS DESIGNERS/CONSULTANTS

CLIENT/SUBJECT ______________ W.O. NO. ______

TASK DESCRIPTION ______________ TASK NO. ______

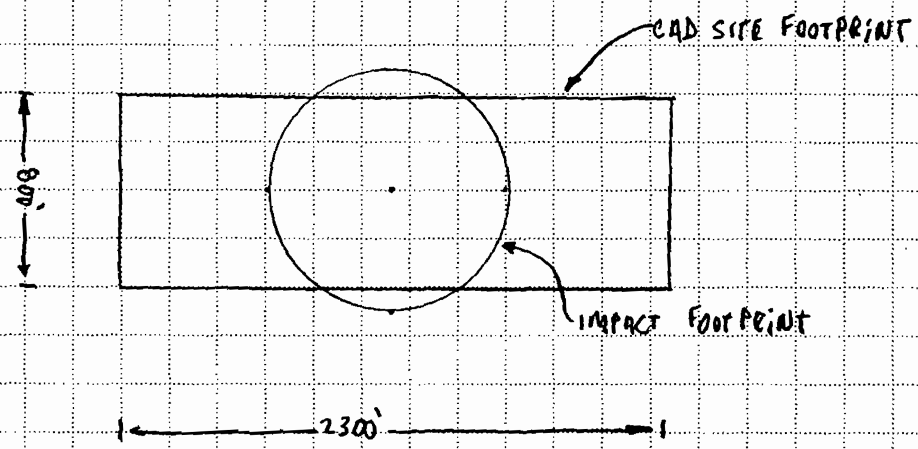
PREPARED BY ________ DEPT ______ DATE ______

MATH CHECK BY ________ DEPT ______ DATE ______

METHOD REV. BY ________ DEPT ______ DATE ______

APPROVED BY ________ DEPT ______ DATE ______

CAD SITE #2
100' DEEP



→ CAD SITE 2 FOOTPRINT IS NEARLY ADEQUATE TO CONTAIN DISCHARGED SEDIMENT

APPENDIX B

CAPPING MATERIAL AVAILABILITY

Sources of Corps Dredged Material for Beneficial Use Projects (Last Revised 9/97)

Corps O&M Navigation Projects/Location	Project Sponsor (Contact Phone #)	Material Ownership (Contact Phone #)	Percent Total Organic Carbon	Percent Sand and Gravel	Grainsize Range (% Sand)	PSDDA Ranking/Testing History	Estimated Quantities Dredged/Dredge Cycle	Recent Historical Disposal/Dredge Method/Last Year Dredged
Bay Center Entrance Channel/Willapa Bay	Port of Willapa 206/942-3422	WDNR 360/902-1083	No data	Sand 99%	No data	Low/never tested	30,000/2 yrs	State open water/ clamshell/'95
Bay Center Channel/ Willapa Bay	Port of Willapa 206/942-3422	WDNR	2%	Silty sand 16%	6-24%	Low/'89	35,000/5 yrs	State open water/ clamshell/'93
Duwamish River Upstream Settling Basin/Seattle	Corps 206/764-3402 (Alex Sumeri)	WDNR/Port of Seattle 206/728-3192	0.4%	Sand & silt 48.33%	88.2-89.3%	Low-moderate/'96, '91, '89, '85	60,000/2 yrs	PSDDA open water and capping at Elliott Bay Outfall, Denny Way, Pier 53, Pier 64 & CAD site/ clamshell/'97
Duwamish River Immediately Downstream of Settling Basin/ Seattle	Corps 206/764-3402 (Alex Sumeri)	WDNR/Port of Seattle 206/728-3192	1.4%	Silt & sand 47.76%	40.7-47.6%	Low-moderate & high/'96, '95, '91, '90, '89, '85	40,000/2 yrs	PSDDA open water/ clamshell/'97
Duwamish River Downstream/Seattle	Corps 206/764-3402 (Alex Sumeri)	WDNR/Port of Seattle 206/728-3192	2-3%	Fine sandy, clayey, silt >50% fines	90-0%	High/limited PSDDA testing	No dredge cycle	Maintained by dredging upstream reaches so minimal material goes downstream
Kenmore/No. End of Lake Washington	King County 206/296-1910	WDNR	3.5%	Silt, clay & sand 50%	28-79%	High/'85, '95	25,000/10 yrs	Upland & PSDDA open water/ clamshell/'87
Keystone Harbor/ Whidbey Island	Corps 206/764-3401 (Hiram Arden)	WDNR	0.2%	Sand & gravel 94%	92-97%	High & low-moderate/'90	25,000/5 yrs	Beach nourishment/ pipeline or clamshell/'90
Oak Bay Canal/Near Hadlock	Corps 206/764-3401 (Hiram Arden)	WDNR	No data	Cobbles & gravel 99%	No data	Low/never tested	10,000/10 yrs	Placement for clam habitat & PSDDA open water/ clamshell/'83
Quillayute River/ LaPush	Quileute Port Authority 360/374-5695	WDNR & Quileute Tribe 360/374-5695	No data	Cobbles, gravel, sand & silt No data	No data	Low/never tested	75-125,000/2 yrs	Beach nourishment & upland/pipeline & clamshell/'95

Sources of Corps Dredged Material for Beneficial Use Projects
(Last Revised 9/97)

Corps O&M Navigation Projects/Location	Project Sponsor (Contact Phone #)	Material Ownership (Contact Phone #)	Percent Total Organic Carbon	Percent Sand and Gravel	Grainsize Range (% Sand)	PSDDA Ranking/Testing History	Estimated Quantities Dredged/Dredge Cycle	Recent Historical Disposal/Dredge Method/Last Year Dredged
Snohomish River Lower/Everett	Port of Everett 206/259-3164 (Dennis Gregor, Hiram is Corp Contact)	WDNR	1%	Sand 70%	92-59%	Low-moderate/'92	250,000/2-3 yrs	PSDDA open water, Jetty Island and Eagle Harbor cap/ clamshell & pipeline/'94
Snohomish River Upper/Everett	Port of Everett 206/259-3164	WDNR	No data	Sand 93%	No data	Low/never tested	250,000/2-3 yrs	Upland rehandling/ pipeline/'92
I&J Waterway/ Bellingham	Port of Bellingham 360/676-2500	WDNR	4%	Sand, silt & clay 31%	25-50%	High/'90	25,000/25 yrs	PSDDA open water/ clamshell/'92
Squalicum Waterway/ Bellingham	Port of Bellingham 360/676-2500	WDNR	1.3%	Silt, sand & clay 30%	1-34%	Moderate/'94, '90	200,000/4 yrs	PSDDA open water/ clamshell/'96
Whatcom Waterway/ Bellingham	Port of Bellingham 360/676-2500 Georgia Pacific	WDNR	2.7%	Clay, silt & sand 38%	5-45%	High/'97, '91	200,000-800,000/25 yrs (range estimates in MTCA RI/FS)	Nearshore fill & open water/ pipeline/'76
Swinomish Channel/ LaConner Vicinity	Port of Anacortes 360/293-3134 Port of Skagit 360/757-0011	WDNR/Swinomish Tribe 360/466-7299	0.04%	Sand 97%	96-100%	Low/'94, '88, '86	35,000/2 yrs	PSDDA open water site, upland preloading and grading/clamshell/ '95
Toke Point Channel/ Willapa Bay	Port of Willapa 360/942-3422	WDNR	1.4%	Silty, sand & clay 47%	45-48%	Low/'87	25,000/4 yrs	Open water/ clamshell/'91
South Reach and West/Grays Harbor	Port of Grays Harbor 360/533-9545	WDNR	No data	Sand No data	No data	Low/never tested	1-1.5 million/annual	Open water, underwater berms & beach nourishment/ hopper/yearly
Cross Over Reach and East/Grays Harbor	Port of Grays Harbor 360/533-9545	WDNR	1.5%	Silt & sand 33%	11-66%	Low/'89, '92, '94, '96	1.5-2 million/annual	Open water/ clamshell & hopper/ yearly

APPENDIX C

GEOTECHNICAL EVALUATION

TECHNICAL MEMORANDUM

QUALITATIVE ASSESSMENT OF POTENTIAL GEOLOGIC HAZARDS
PUGET SOUND RESOURCES
MARINE SEDIMENTS UNIT FEASIBILITY STUDY ALTERNATIVES

INTRODUCTION

Geologic hazards assessment methodology is applied to the feasibility study for the PSR MSU alternatives to provide decision-makers with a qualitative assessment of the relative risks to each alternative from geologic hazards. Alternatives are evaluated for both static and dynamic (sub-catastrophic) conditions.

Each of the general remedy responses compiled into the various alternatives for the MSU can be designed and constructed at the site. The site-specific conditions (location on the delta, slopes, geotechnical properties of the sediments, etc.) do not present any new or inordinate difficulties or escalated costs in implementation, given standard of care in design and construction. Assuming that a thorough geotechnical investigation is conducted during design that considers design factors (slope stability, settlement/consolidation, seismicity, wave action, etc.), all the general remedy responses can meet remedy performance requirements, and have been implemented is some form or another at ports and harbors with similar conditions throughout the world. As such this memo addresses the potential risk from geologic hazards in the form of relative operation and maintenance costs associated with the remedy.

GEOLOGIC SETTING

The Duwamish River-mouth delta is located in central Puget Sound, part of the Puget Lowland. The Puget Lowland is a complex topographic and structural basin formed during the Quaternary Period. The lowland has been repeatedly glaciated, resulting in the accumulation of a thick sequence of glacial and nonglacial sediments. The depth to bedrock varies considerably, but beneath the river-mouth delta it is estimated to be between 100 to 200 m (Yount et al., 1985).

Ice from the most recent glacial advance, the Vashon Stade of Fraser Glaciation (Armstrong et al., 1965) occupied the Puget Lowland between 11,000 to 13,000 years ago. Ice thickness is estimated to have been about 1000 m at its maximum near the delta during Fraser Glaciation (Thorson, 1981). The topography and geomorphology are primarily a result of the last glaciation. The overall landscape has changed little since the ice retreated except as related to relative fluctuations in sea level, adjustments in river gradients, and formation of prograding deltas. The present day low, undulating topography exhibits wide, flat valleys that support underfit rivers.

Duwamish River-Mouth Delta

The topography of the Duwamish valley was substantially different compared to its present configuration following the last glaciation. During the Fraser Glaciation, sea level was lower than present and melt water streams eroded deeply into the landscape, capturing drainages and changing river flow directions as the ice retreated. Since that time, rising sea-level conditions, influenced by both eustatic and isostatic adjustments, have resulted in aggradation of the former Duwamish embayment by the Green, Black and Cedar rivers (Dragovich et. al 1994) and construction of the river-mouth delta which now covers about 6 sq. km.

The delta complex has been constructed in a reentrant of Puget Sound (former Duwamish embayment). The postglacial delta has been built with sediment supplied by rivers. The upland bluffs that fringe the former Duwamish embayment consists primarily of overconsolidated glaciogenic sediments. The river-mouth delta is located 2 km short of the embayment entrance; the intervening water body forms Elliott Bay. The delta is no longer prograding, as the sediment supply of the Duwamish River no longer exceeds the reworking and transport ability of the local marine environment.

Dams, diverting of the Black and Cedar rivers (Chrzastowski, 1983) and maintenance dredging have drastically depleted the historical bed-load sediment supply. Recent analysis (GeoSea, 1994) suggests the major source of sediment supplied to the delta front occurs from shoreline sources and sediment transport in a clockwise gyre in Elliott Bay, which is dominant over the Duwamish River source. GeoSea (1994) indicates sediment transport is in dynamic equilibrium. The current interpretation is that the delta is in a stagnant phase of development, neither prograding nor receding. Historical submarine morphological changes to the delta involve thin veneers of soft muds in littoral transport and or loose submarine delta front fills. The historical veneer sediments receive further discussion later in this memorandum.

The thickness of the normally consolidated postglacial deltaic sediments is on the order of 5 to 10 m near the shore and is greater than 100 m at the northern margin of the delta. Historically, breakwater construction and dredging and filling activities have modified the near-shore deltaic deposits (Galster and Laprade, 1991). Fill ranges from 1 m to more than 10 m thick. The PSR Upland Unit, the Lockheed facility, and Harbor Island are current fills on the historical deltaic deposit and have been in place in their current form for 30 to 100 years.

Stratigraphy

The gross stratigraphy and engineering geologic units defined for the delta are not complex. The units consist of laterally extensive graded sequences of sand, silt, and clay that exhibit internally consistent and generally uniform engineering properties.

Many components of field explorations and laboratory data have been used to identify and distinguish the various engineering properties of the geologic units that comprise the delta.

Hollow-stem auger drilling and standard penetration sampling, vibracore sampling, and cone penetration testing provided useful and complementary information. The soil samples obtained by drilling were visually examined and classified by particle size, textural characteristics, and gradation.

The internal structure of a prograding delta reflects its external shape and the processes that formed it. The internal deltaic structure can be divided into three basic components: topset, foreset, and bottomset beds. This sequence is present in the Duwamish River-mouth delta (RETEC, 1998; WESTON, 1998) and is very similar to the structure and characteristics of the Snohomish (Fuller et al., 1989) and Puyallup (Hart-Crowser, undated) River-mouth deltas.

HOLOCENE/RECENT DELTAIC STABILITY

With the pending remedial action occurring on the Duwamish river-mouth delta, overall delta stability is a major geotechnical concern. In light of the inherent instability of deltaic (liquefiable) soils and data related to neotectonics of the Pacific Northwest, an attempt to evaluate the stability of the delta during the Holocene epoch (the last 10,000 years) has been made. Engineering geologic studies included evaluating information related to historic and prehistoric mass wasting conditions on the delta. Historic and prehistoric mass wasting was evaluated by analysis of bathymetric, geophysical, cone penetrometer, and borehole data.

Mass wasting is a common geologic process in the formation and development of actively prograding deltas. Failures resulting from both static and dynamic conditions are of interest in developing facilities on deltaic sediments. Mass-wasting processes may include slumps, sediment slides, and sediment flows. Most mass-wasting events occur under static failure conditions. Mass-wasting processes occur regularly along the more active portions of prograding delta fronts.

Dynamic forces, such as storms and earthquake-induced strong ground motion, can trigger mass-wasting events that are typically larger in scale than static condition events. Engineering analysis indicates that some of these delta soils could liquefy under design earthquake loading. The seismicity of the Pacific Northwest is briefly discussed in the following section as it pertains to the potential for dynamically induced mass wasting.

Seismicity

Seismicity in the greater Puget Sound region is largely controlled by the complex interaction of two major crustal plates: the continental North American plate and the oceanic Juan De Fuca plate offshore to the west (Heaton and Kanamori, 1984). Good evidence for prehistoric earthquakes in the Puget Lowland has been presented in the past few years (QRC, 1993). Atwater (1987) originally presented rather convincing evidence in support of large prehistoric events, of probable seismic origin, along the coast of Washington. The mechanism for these large events may have included large-scale thrust faulting. The possible effects of such events can only be postulated, but strong ground motion would be expected in the lowland (Ihnen and Hadley, 1985). Johnson and others (1994) recently mapped the Seattle fault beneath the Duwamish delta; they describe the fault as having predominately reverse or thrust displacement.

Historical seismic events in the Puget Sound region appear to result from two mechanisms. East-west compression from the interaction of the two crustal plates is postulated to be responsible for shallow (5 to 15 km) and comparatively small (typically less than magnitude 6) earthquakes. Deeper (30 to 50 km) and frequently larger (Richter magnitude 7 to 8+) earthquakes are postulated to be related to subducted oceanic lithosphere (Juan de Fuca plate).

Most historical Puget Sound earthquakes have been concentrated in a north-trending belt about 100 km wide centered on the lowland. Within this belt, seismic activity increases from north to south, reaching a maximum in the area from Seattle to Olympia. Historical documentation of earthquakes exists for the past 140 years. The record is fairly complete for large magnitude events (Modified Mercalli Intensity of VII or greater, below) and is incomplete for smaller earthquakes.

Earthquake	Date	Modified Mercalli Intensity (at epicenter)	Richter Scale Magnitude
North Cascades	15DEC1872	VIII+	7.5
Puget Sound	12DEC1880	VI –VII	5.8
North Olympia	13NOV1939	VII	5.7
Pickering Passage	15FEB1946	VII	5.7
Straight of Georgia	23JUN1946	VIII+	7.3
Olympia	13APR1949	VIII	7.1
Seattle-Tacoma	29APR1965	VII	6.5

The Duwamish River-mouth delta experienced an undetermined level of ground motion from the Olympia, 1949, and Seattle-Tacoma, 1965, earthquakes. Major damage was not reported at the delta from either event. The only significant port damage reported in the Puget Sound during those earthquakes involved movement of a bulkhead on Harbor Island and some ground failure at the Port of Olympia.

Historical Stability Assessment

Review of recent bathymetric survey data (NOAA, 1970,1995) did not identify any submarine topographic anomalies indicative of mass wasting of the delta massif. Topographic anomalies in bathymetry are all interpreted as historic fills and disposal sites. This suggests that the delta has not experienced historical ground motion of sufficient acceleration to induce major failures.

Sedimentation rates greatly influence submarine mass wasting due to static loading of the delta. The bathometric survey data suggested that sedimentation rates in the portion of the delta were low, which indicated minimal loading is occurring on the delta from this source.

Side-scan sonar and seismic reflection data (Kayen and others, 1995) showed the native (deltaic) sediment to be homogeneous and non-internally reflecting. No acoustic contrasts were identified that reflected instability in the deltaic sediment. All characteristics of submarine slides or flows were limited to the post-turn of the century veneer sediment and fills. Geophysical survey lines and scans of the anomalous geomorphic expression in the delta front did not reveal any seismic signatures indicative of mass wasting of the delta proper.

No anomalous stratigraphic data were observed in any of the numerous subsurface explorations into the delta suggestive of past instabilities.

Discussion

Mass wasting is characteristic of actively prograding deltas where sediment supply rates exceed natural consolidation and/or erosive forces. The Puyallup delta (Hart Crowser, 1975) is a classic example. In contrast, the distal southwestern portion of the Snohomish River delta, with its low sedimentation rate has been stable throughout recent geologic time (Fuller and others, 1989). Static condition mass wasting is not anticipated to be a significant contributor to geologic hazards involving the Duwamish delta sediment proper, given standard care and engineering practice to design and construction, because conditions on the Duwamish River delta are relatively static as a result of the extremely low historical sedimentation rates.

Sub-catastrophic seismically induced dynamic conditions have a very high probability of adversely affecting the proposed feasibility study remedies. The delta has experienced moderate seismic energy in recorded history without catastrophic results, or even recognizable submarine mass wasting. The delta is not expected to behave differently, under similar conditions, over the remedy design life. As such, the focus of geologic hazards is on the veneer of recent sediments on the delta structure proper and on proposed remedy structures (caps or fills).

Dynamically induced sea waves capable of causing either direct or collateral damage to engineered structures would be associated with a catastrophic event, which is not addressed herein.

Veneer Sediments

Historical accumulations of veneer sediments on the delta front are typically soft, non-cohesive, low strength muds of high water content, containing organic detritus (Kayen and others, 1995) and may contain spent wood treating liquids (WESTON, 1998). Under dynamic conditions these sediments are expected to de-water through consolidation, and with increased density, flow as discreet submarine slides or sheet-flow. The softest fraction would likely be resuspended in the water column. The slide plane for the dynamically induced failure would likely coincide with the underlying relatively dense and cohesive delta sediment. Limited or localized scouring of the delta sediment may occur near the head scarp.

Engineered structures (caps or fills) placed on these soft, veneer sediments, which are stable under static conditions, could be damaged by seismically induced differential settlement or sediment flow. In cases where the unit weight of the engineered structure exceeds that of the veneer sediments, such contrast may exacerbate the extent of flow.

Soft sediment deformation in the form of diapirs or lateral flow (squeezing) could be expected under lower energy dynamic conditions, where higher unit weight engineered structure's rest on soft sediments. At a minimum this deformation would manifest itself as hummocky surfaces in the engineered cover. In more extreme cases, breaches in the cover may develop as "mud boils" or longitudinal fissures.

The proposed nearshore fill requires an engineered berm to contain sediments. The engineering stability analysis of the conceptual design suggests it will be stable with a factor of safety greater than 1.5 under static conditions. The potential for damage to the berm exists if subjected to dynamic accelerations greater than 0.1g (see attached geotechnical slope stability analysis). Collateral damage from liquefaction could be expected to affect facility integrity under higher accelerations.

GEOLOGIC HAZARDS ASSESSMENT OF ALTERNATIVES

Relative geologic hazard potential from either static or dynamic forces is provided for the various alternatives in terms of potential for remedy impairment. Remedy impairment translates to maintenance cost for purposes of comparing alternatives.

Alternative 1- No Action

There are no engineered fills or structures in this alternative and therefore no geologic hazards are addressed. The existing slope has low potential for flow sides to develop under static conditions because of minimal loading from historical sedimentation rates.

Alternative 2 – Dredging to CSL

This alternative consists of four components; shoreline capping, dredging, capping in the groundwater discharge zone and deepwater capping. This alternative has the lowest potential for geologic hazard-related remedy impairment due to the relatively small area (14 acres) of cap.

Dredging in the highly contaminated area will reduce the potential for localized sediment flow by removal of the unconsolidated veneer sediments. Dredged side slopes will be constructed to minimize slumping of material remaining in place.

Alternative 3a - Capping to SQS

This alternative consists of four components: shoreline capping, capping in the groundwater discharge zone, Crowley Marine and other nearshore areas, and deep water capping. This alternative has the highest potential for geologic-hazard related remedy impairment due to the largest area (96 acres) capped. The proposed area-wide capping in the highly contaminated area will create a large potential for hummocky surfaces, mud boils or longitudinal fissures in the cap under static conditions. No veneer sediments with the potential to flow will be removed under this alternative.

Alternative 3b – Capping to CSL

This alternative consists of four components; shoreline capping, capping in the highly contaminated area, dredging and capping in the groundwater discharge zone and Crowley Marine area. This alternative has the third highest potential for geologic hazard-related remedy impairment due to the relatively large area (47 acres) of capping. The proposed area-wide capping in the highly contaminated area will create a large potential for hummocky surfaces, mud boils or longitudinal fissures in the cap under static conditions. The dredging prior to capping in the shoreline cap, Crowley Marine area and groundwater discharge zone cap will minimize potential for cap damage by deformation.

Alternative 4a – Fill Area Removal to SQS and Capping

This alternative consists of five components; shoreline capping, dredging in the highly contaminated fill area, capping all remaining offshore areas exceeding SMS, dredging and capping in the groundwater discharge zone and Crowley Marine area. This alternative has the second highest potential for geologic hazard-related remedy impairment due to the large area (73 acres) of cap. The proposed area-wide capping will have some potential for cap deformation; however, the contaminated layer in the area to be capped is relatively thin. The proposed dredging will minimize the potential for dynamically induced localized flow slides in the veneer sediments.

Alternative 4b – Fill Area Removal to CSL and Capping

This alternative consists of five components: shoreline capping, dredging in the highly contaminated fill area, capping in the remaining offshore areas that exceed CSL in the surface sediments, dredging and capping in the groundwater discharge zone and Crowley Marine area. This alternative has the second lowest potential for geologic hazard-related remedy impairment due to the relatively small area (24 acres) of capping. The proposed cap will have a low potential for deformation because the contaminated layer is relatively thin in the area to be capped. The proposed dredging will eliminate the potential for localized flow slides in the veneer sediments

CAD Sites Option

Confined aquatic disposal sites are subject to the same geologic hazard potential as capping without dredging in the all the alternatives. CAD has a relatively higher potential for adverse performance that the near shore disposal site due to the inability to provide construction quality control.

Nearshore Disposal Site Option

This option is subject to the same hazard potential as capping without dredging and CAD in the all the alternatives. Nearshore disposal has a relatively lower potential for adverse performance than the CAD disposal site due to the ability to provide construction quality control.

Upland Disposal Site Option

Offshore geologic hazards do not apply to the upland disposal option.

CONCLUSION

The Duwamish River-mouth deltaic stratigraphy is relatively simple and is internally consistent in comparison to other Puget Sound deltas. The stratigraphic sequence reflects a combination of late-glacial and postglacial geologic processes. Limited direct and indirect evidence obtained from the delta supports an interpretation of both short- and long-term stability with respect to large-scale mass-wasting processes. The alternatives are located on a portion of the delta where current sedimentation rates are extremely low. These low rates substantially reduce the probability and frequency of mass-wasting events under static conditions. Substantial changes to sedimentation rates in the future are not anticipated. Historically, mass wasting has not significantly changed the gross morphology of the delta, as indicated by the bathymetric and geophysical surveys. Data from borings and cone penetrometer probes indicate the delta complex near the port has been historically stable.

All alternative components (dredging, capping, berm construction, etc.) are subject to the same risk potential, regardless of alternative. The difference between alternatives is a function of the sizes of the engineered action (e.g. the larger the cap the greater the potential for O&M resulting from geologic hazards). The *differentiator* between alternatives is the relative cost of O&M. Given that the estimated range in cost for all alternative is within 50% of one another, the relative O&M (i.e., geologic hazard potential) is not a significant discriminator in remedy selection.

Below, alternatives are ranked from lowest to highest potential for geologic hazard induced maintenance costs;

Alternative 2 has the lowest potential for geologic hazard induced maintenance costs. Alternatives 3a and 4a have the highest potential of impairment and are similar in magnitude. Alternative 3b has a moderate potential for remedy impairment by geologic hazards. Alternative 4b has the second lowest. Sub-catastrophic geologic hazards have greater potential to cause impairment to the CAD option than the near shore fill disposal option.

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ATTACHMENT TO

TECHNICAL MEMORANDUM

QUALITATIVE ASSESSMENT OF POTENTIAL GEOLOGIC HAZARDS PUGET SOUND RESOURCES SEDIMENT UNIT FEASIBILITY STUDY ALTERNATIVES

GEOTECHNICAL SLOPE STABILITY EVALUATION

BACKGROUND

This evaluation address geotechnical stability of a proposed berm to contain the dredged materials proposed in a nearshore fill disposal facility. This analysis evaluates the feasibility of building the berm and the associated stability of the disposal site. These analyses have order of magnitude accuracy for conceptual purposes to determine the potential success of constructing such a disposal facility. This analysis should not be used for final design. In order to complete a final design, additional geotechnical data should be collected along the berm alignment with depth. Additionally, a more rigorous analysis of each aspect of the design must be performed for final design.

MATERIAL PROPERTIES

Borings were completed in the area of concern to determine the soil profile and material properties. Based on the borings (EB016, EB114), the simplified soil profile is a 10 ft. layer of soft sandy silt underlain by interbedded soft silt, loose silty sand, and sandy silt to a depth of 75 ft. below which the materials become more dense. Borings were drilled to a depth of 96 ft. and no bedrock was encountered. The existing bottom is at a slope of approximately 12 percent.

Laboratory tests were run on shallow samples (less than 10 ft.) to determine the material properties. The tests run included grain size, 1-D consolidation, density, moisture content, and triaxial shear tests. The test results are provided in the PSR Remedial Investigation and are summarized in Table GT-1. These results were used to determine the representative properties used in the stability and settlement analyses.

In order to determine the friction angle of the materials a p-q diagram (Figure GT-2) was plotted. This is a plot of the peak failures for each triaxial test and shows that the data is consistent for the various samples and that the friction angle is approximately 32 degrees.

CONSOLIDATION/SETTLEMENT

Settlement of a soil layer is made up of several components; immediate settlement, consolidation, and secondary consolidation. Immediate settlement occurs as the load is placed on a layer of soil. There is no time lag between when the load is placed and the time settlement occurs. This type of settlement is associated with sands. Consolidation occurs when there is a time lag between when the load is placed and the settlement occurs. Consolidation can consist of primary and secondary consolidation. For the purposes of this analysis, only primary settlement has been considered. Secondary settlement considerations would be required for design.

Based on laboratory data, it is estimated that as much as 12 inches of settlement and/or consolidation could occur due to construction of the berm. The consolidation could occur over 2 to 10 years.

SLOPE STABILITY

A slope stability analysis has been performed to determine the factor of safety against failure due to both static and dynamic loading. As shown on Figure GT-3, the factor of safety for a 1.5:1 slope is only 1.13 for static conditions and 0.92 under a seismic loading of 0.1 g. In order to have a factor of safety of 1.5 under static conditions and 1.0 under seismic conditions a slope of 2.5 to 1 is necessary.

LIQUEFACTION

Silty sands are the most common type of soil involved in both static and earthquake induced liquefaction. Based on the low density of the materials and the high moisture contents there is a high potential for liquefaction. Additional geotechnical analysis will be required to determine how the potential could be mitigated.

EROSION

Erosion due to wave action will be a significant design element. Proper sizing of rock protection will be necessary to protect the berms.

SUMMARY

Based on the limited data and subsequent analyses, the disposal facility will be stable as configured. A slope of 2.5 to 1 on the outer face will provide a factor of safety of 1.5 under static conditions. The facilities stability could be effected under earthquake loading of 0.1g or greater.

Liquefaction could be expected to significantly affect the facilities integrity under seismic loading.

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						PSR Marine Sediment									
Sample	Depth	Insitu Density	Test Density	Specific Gravity	P.I.	% -200	Cc	Cv	Sigma 1	Sigma 3	p	q	Phi /bar	Lab Phi	Lab C
EB016	.8-1.3	73.7	85.7	2.66	2	83			5937	1426	3682	2256	31.5	30.0	215
	1.3-1.8	42.9	50.7	2.51	10	81			1266	259	763	504	33.5	33.2	0
	4.6-4.8		49.1				0.152	2.0							
	5-5.5	70.2	79	2.72	10	85			2470	634	1552	918	30.6	32.1	0
	5.5-6.0	28.2	38.5	2.7					3663	245	1954	1709	41.2	41.2	0
EB114	1.8-2.0		73.6				0.138	0.2							
	1.3-1.5		68.2				0.131	1.0							
	5.3-5.5		79.2				0.062	4.0							
	4.9-5.4	76.9	92.7	2.7	12	21			11847	2650	7249	4599	32.4	32.9	0
	5.5-6.0	81.2	91	2.67	9	37			7913	1947	4930	2983	31.2	31.6	0
				curve fit		y=.6326x		x=	500	y=	316.3				
							0.63								
						Phi=	**32.3**								
p=(sigma1 + sigma3)/2			PI=plasticity index												
q=(sigma1-sigma3)/2			Cc=consolidation factor												
C=cohesion			Cv=consolidation time factor												
Phi=friction angle															

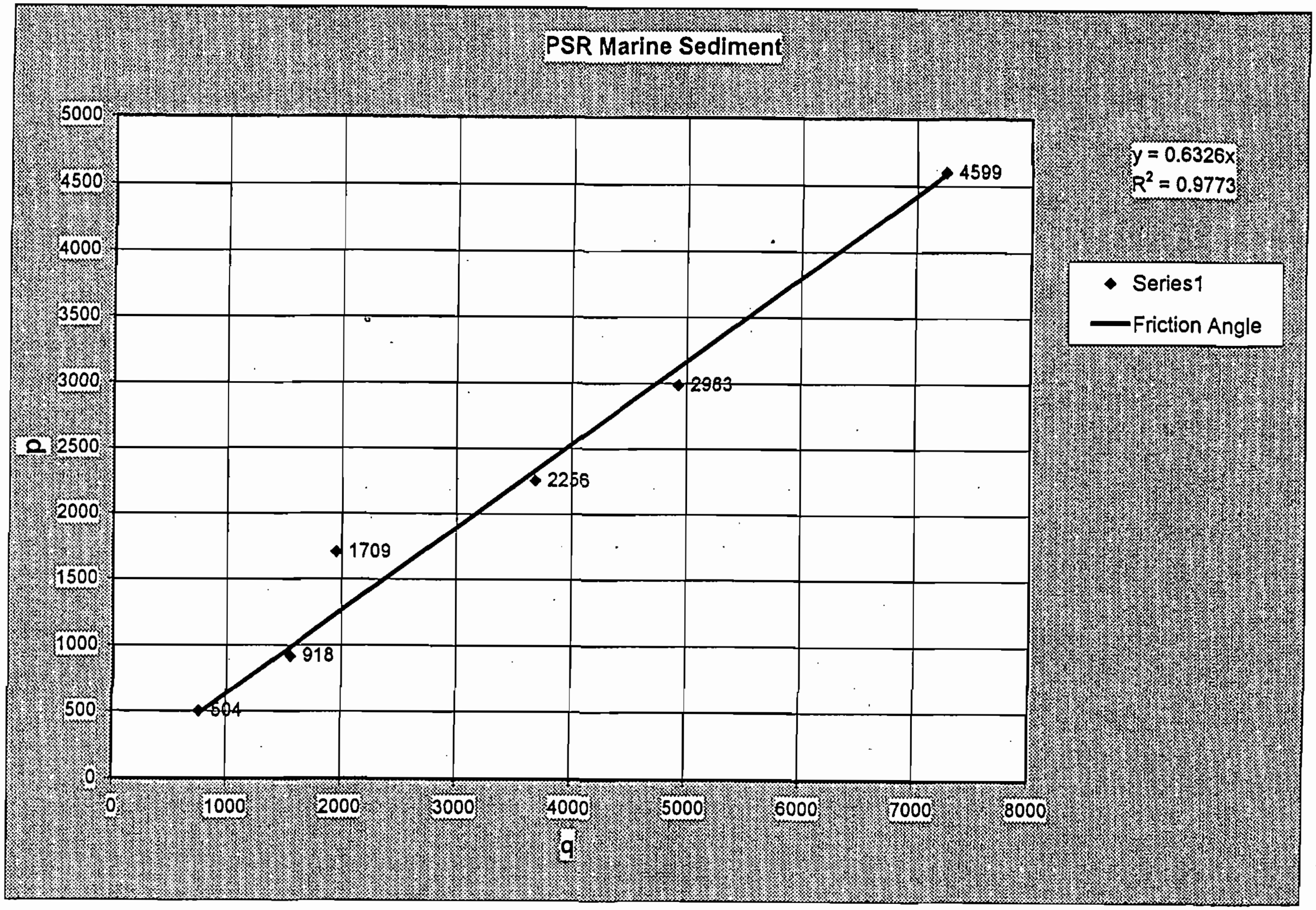
PSR MARINE SEDIMENT

WESTON MANAGERS DESIGNERS/CONSULTANTS

TABLE

GT-1

98-0529.TBL

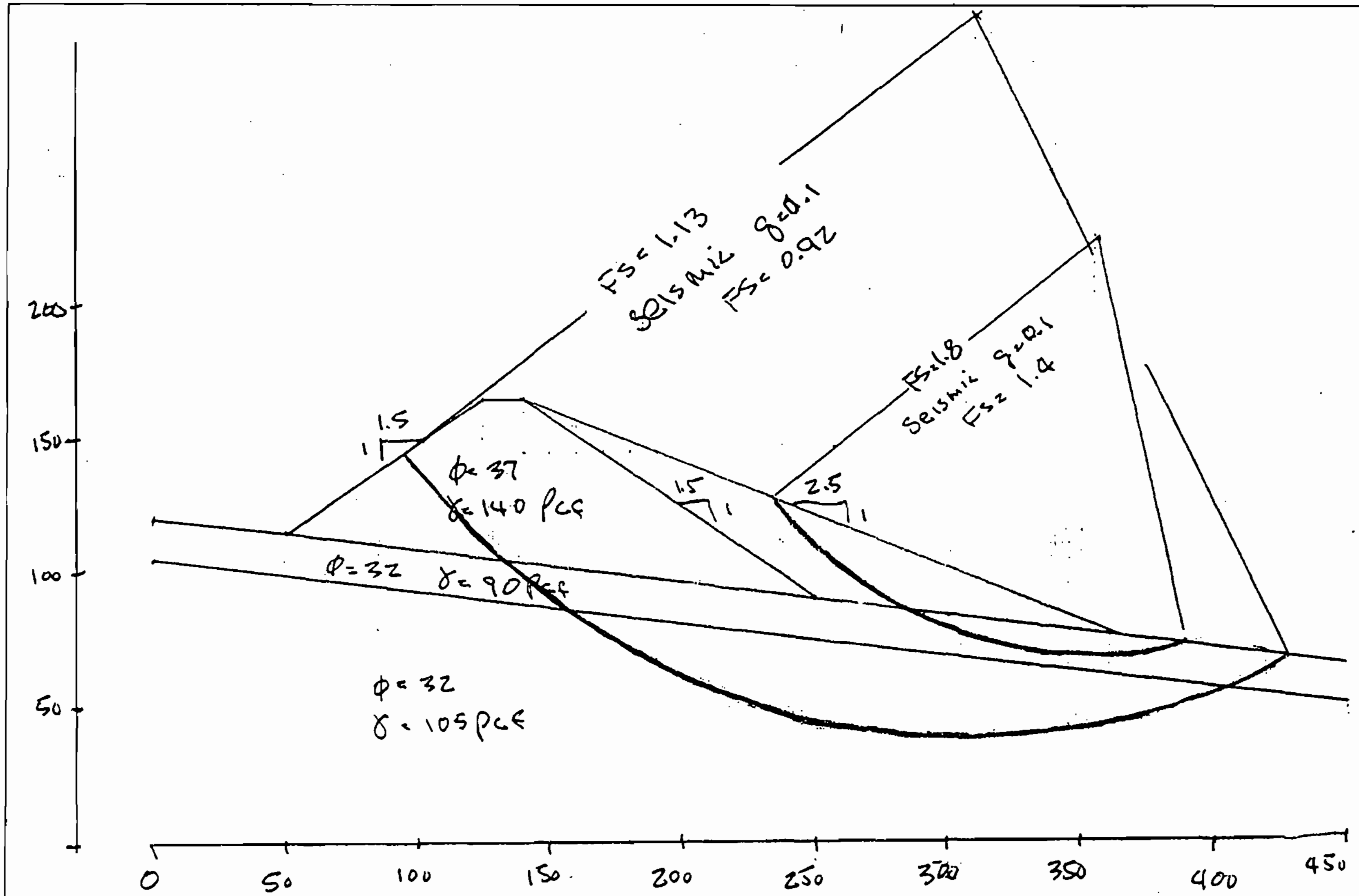


PSR MARINE SEDIMENT

WESTON MANAGERS DESIGNERS/CONSULTANTS

FIGURE
GT-2

98-0529b.FIG



PSR MARINE SEDIMENT

WESTON
MANAGERS DESIGNERS/CONSULTANTS

FIGURE
GT-3

98-0529A.FIG

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FAILURE CIRCLE CALCULATIONS

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WESTON MANAGERS DESIGNERS/CONSULTANTS

SHEET ____ of ____

CLIENT/SUBJECT PSR Marine W.O. NO. ____

TASK DESCRIPTION Settlement TASK NO. ____

PREPARED BY [initials] DEPT ____ DATE 8/24/98

MATH CHECK BY ____ DEPT ____ DATE ____

METHOD REV. BY ____ DEPT ____ DATE ____

APPROVED BY ____ DEPT ____ DATE ____

Soil Profile
(Generalized)

$\Delta P = 5000$ pcf

Layer 1 10' $e_0 = \cancel{1.30}\ 1.6$ $\gamma = 90$ pcf

Layer 2 50' $e_0 = \cancel{1.0}\ 1.2$ $\gamma = 105$ pcf

$$\Delta H = \frac{C_c}{1+e_0}\left(\log_{10}\frac{P_0+\Delta P}{P_0}\right)$$

Assume from Testing $C_c =$ 1.4 Avg of 3 tests.

$$= \frac{1.4}{1+1.6}\left(\log\left(\frac{900+5000}{900}\right)\right)$$

Layer 1

$P_0 = 10 \times 90 = 900$

$$+ \frac{1.4}{1+1.2}\left(\log\frac{6150+5000}{6150}\right)$$

Layer 2

$P_0 = 50 \times 105 = 5250$

$$= .44 + .16 = .6 \text{ ft}$$

RFW 10-05-003/A-5/85
512-5643

WESTON
MANAGERS DESIGNERS/CONSULTANTS

SHEET 2 of ____

CLIENT/SUBJECT ____ W.O. NO. ____

TASK DESCRIPTION ____ TASK NO. ____

PREPARED BY ____ DEPT ____ DATE ____

MATH CHECK BY ____ DEPT ____ DATE ____

METHOD REV. BY ____ DEPT ____ DATE ____

APPROVED BY ____ DEPT ____ DATE ____

Time for Settlement

$$t = \frac{T H^2}{C_V}$$

T = .848 for 90% Consolidation

Assume Cv = 2 ft²/day from LAB tests (Range is .2 to 4)

$$= \frac{.848 \times 60^2}{2}$$

= 1526 days

4.2 yrs

H = 60 ft

RFW 10-05-003/A-5/85
512-5643

SLOPE STABILITY MODEL OUTPUT

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PSR Marine Sediment   PSR.IN

CASE NUMBER 1
Summary of Lowest Factors of Safety

Coordinates (x,y)		Seepage Cond	Radius	Factor of Safety
200.000	160.000	1	34.013	1.281
212.000	154.000	1	36.917	1.310
224.000	148.000	1	38.373	1.289
236.000	142.000	1	39.829	1.269
248.000	136.000	1	41.285	1.251
260.000	130.000	1	43.756	1.385
224.000	160.000	1	48.381	1.251
236.000	154.000	1	49.837	1.237
248.000	148.000	1	51.293	1.224
260.000	142.000	1	52.748	1.211
272.000	136.000	1	59.125	2.143
284.000	130.000	1	75.529	3.374
248.000	160.000	1	61.300	1.206
260.000	154.000	1	62.756	1.196
272.000	148.000	1	65.186	1.735
284.000	142.000	1	79.814	2.792
296.000	136.000	1	104.066	3.773
308.000	130.000	1	130.000	4.591
272.000	160.000	1	75.217	1.444
284.000	154.000	1	85.039	2.357
296.000	148.000	1	103.805	3.251
308.000	142.000	1	136.463	4.032
320.000	136.000	1	136.000	4.821
332.000	130.000	1	55.415	5.288
296.000	160.000	1	107.282	2.836
308.000	154.000	1	130.902	3.573
320.000	148.000	1	148.000	4.243
332.000	142.000	1	142.000	5.112
344.000	136.000	1	62.792	5.231
356.000	130.000	1	58.259	5.251
320.000	160.000	1	160.000	3.810
332.000	154.000	1	154.000	4.502
344.000	148.000	1	74.701	5.173
356.000	142.000	1	70.168	5.186
368.000	136.000	1	65.636	5.201
380.000	130.000	1	61.923	5.273

AT POINT (260.000, 154.000),RADIUS 62.756
THE MINIMUM FACTOR OF SAFETY IS 1.196

260.000	154.000	1	62.756	1.196
270.000	154.000	1	69.137	1.455
250.000	154.000	1	57.373	1.210
260.000	164.000	1	71.095	1.186
260.000	174.000	1	79.435	1.179
260.000	184.000	1	87.774	1.173

260.000	194.000	1	96.114	1.168
260.000	204.000	1	104.453	1.164
260.000	214.000	1	112.793	1.160
260.000	224.000	1	121.132	1.157
260.000	234.000	1	129.472	1.155
260.000	244.000	1	137.811	1.152
260.000	254.000	1	146.151	1.150
260.000	264.000	1	154.490	1.149
260.000	274.000	1	162.830	1.148
260.000	284.000	1	171.169	1.160
270.000	274.000	1	168.213	1.144
280.000	274.000	1	173.596	1.140
290.000	274.000	1	188.923	1.231
280.000	284.000	1	181.935	1.139
280.000	294.000	1	190.275	1.138
280.000	304.000	1	198.614	1.143
290.000	294.000	1	195.658	1.136
300.000	294.000	1	210.769	1.249
290.000	304.000	1	203.997	1.135
290.000	314.000	1	212.337	1.137
300.000	304.000	1	209.380	1.133
310.000	304.000	1	214.763	1.130
320.000	304.000	1	225.997	1.396
310.000	314.000	1	232.615	1.276
310.000	294.000	1	207.442	1.137
312.500	304.000	1	217.131	1.136
307.500	304.000	1	213.418	1.131
310.000	306.500	1	216.848	1.130
310.000	309.000	1	218.933	1.130
310.000	311.500	1	230.487	1.284
312.500	309.000	1	221.310	1.136
307.500	309.000	1	227.154	1.269

AT POINT (310.000, 309.000),RADIUS 218.933
THE MINIMUM FACTOR OF SAFETY IS 1.130

PSR Marine Sediment   Seiesmic   g=0.1   PSRs.IN

CASE NUMBER 1
Summary of Lowest Factors of Safety

Coordinates (x,y)		Seepage Cond	Radius	Factor of Safety
200.000	160.000	1	34.013	1.056
212.000	154.000	1	36.917	1.083
224.000	148.000	1	38.373	1.063
236.000	142.000	1	39.829	1.045
248.000	136.000	1	41.285	1.029
260.000	130.000	1	43.756	1.126
224.000	160.000	1	48.381	1.030
236.000	154.000	1	49.837	1.017
248.000	148.000	1	51.293	1.005
260.000	142.000	1	52.748	0.994
272.000	136.000	1	57.179	1.648
284.000	130.000	1	68.840	2.468
248.000	160.000	1	61.300	0.989
260.000	154.000	1	62.756	0.980
272.000	148.000	1	65.186	1.363
284.000	142.000	1	75.030	2.078
296.000	136.000	1	89.977	2.738
308.000	130.000	1	52.571	2.959
272.000	160.000	1	75.217	1.161
284.000	154.000	1	83.123	1.787
296.000	148.000	1	95.342	2.381
308.000	142.000	1	64.480	2.910
320.000	136.000	1	59.948	2.922
332.000	130.000	1	55.415	2.936
296.000	160.000	1	101.633	2.103
308.000	154.000	1	115.195	2.599
320.000	148.000	1	71.857	2.885
332.000	142.000	1	67.324	2.893
344.000	136.000	1	62.792	2.904
356.000	130.000	1	58.259	2.915
320.000	160.000	1	136.404	2.762
332.000	154.000	1	79.234	2.864
344.000	148.000	1	74.701	2.871
356.000	142.000	1	70.168	2.878
368.000	136.000	1	65.636	2.887
380.000	130.000	1	61.923	2.927

AT POINT (260.000, 154.000),RADIUS 62.756
THE MINIMUM FACTOR OF SAFETY IS 0.980

260.000	154.000	1	62.756	0.980
270.000	154.000	1	69.137	1.169
250.000	154.000	1	57.373	0.993
260.000	164.000	1	71.095	0.971
260.000	174.000	1	79.435	0.965
260.000	184.000	1	87.774	0.959

260.000	194.000	1	96.114	0.955
260.000	204.000	1	104.453	0.951
260.000	214.000	1	112.793	0.948
260.000	224.000	1	121.132	0.945
260.000	234.000	1	129.472	0.943
260.000	244.000	1	137.811	0.941
260.000	254.000	1	146.151	0.939
260.000	264.000	1	154.490	0.937
260.000	274.000	1	162.830	0.937
260.000	284.000	1	171.169	0.946
270.000	274.000	1	168.213	0.933
280.000	274.000	1	173.596	0.930
290.000	274.000	1	188.923	1.008
280.000	284.000	1	181.935	0.929
280.000	294.000	1	190.275	0.928
280.000	304.000	1	198.614	0.932
290.000	294.000	1	195.658	0.926
300.000	294.000	1	210.769	1.019
290.000	304.000	1	203.997	0.925
290.000	314.000	1	212.337	0.926
300.000	304.000	1	209.380	0.923
310.000	304.000	1	214.763	0.921
320.000	304.000	1	225.997	1.124
310.000	314.000	1	232.615	1.038
310.000	294.000	1	207.442	0.927
312.500	304.000	1	217.131	0.926
307.500	304.000	1	213.418	0.921
310.000	306.500	1	216.848	0.921
310.000	309.000	1	218.933	0.921
310.000	311.500	1	230.487	1.044
312.500	309.000	1	221.310	0.926
307.500	309.000	1	227.154	1.033

AT POINT (310.000, 309.000),RADIUS 218.933
THE MINIMUM FACTOR OF SAFETY IS 0.921

PSR Marine Sediment   2.5:1 Slope   PSR25.IN

CASE NUMBER 1
Summary of Lowest Factors of Safety

Coordinates	(x,y)	Seepage Cond	Radius	Factor of Safety
200.000	160.000	1	22.386	2.306
212.000	154.000	1	22.637	2.443
224.000	148.000	1	21.305	2.460
236.000	142.000	1	19.974	2.478
248.000	136.000	1	18.643	2.500
260.000	130.000	1	17.312	2.526
224.000	160.000	1	32.485	2.241
236.000	154.000	1	31.154	2.243
248.000	148.000	1	29.823	2.245
260.000	142.000	1	28.491	2.247
272.000	136.000	1	27.160	2.249
284.000	130.000	1	25.829	2.252
248.000	160.000	1	41.003	2.140
260.000	154.000	1	39.671	2.138
272.000	148.000	1	38.340	2.136
284.000	142.000	1	37.009	2.134
296.000	136.000	1	35.677	2.131
308.000	130.000	1	35.458	2.185
272.000	160.000	1	49.520	2.077
284.000	154.000	1	48.188	2.074
296.000	148.000	1	46.857	2.070
308.000	142.000	1	46.648	2.110
320.000	136.000	1	45.262	2.105
332.000	130.000	1	43.876	2.100
296.000	160.000	1	58.037	2.034
308.000	154.000	1	57.837	2.065
320.000	148.000	1	56.451	2.060
332.000	142.000	1	72.453	2.021
344.000	136.000	1	65.302	1.911
356.000	130.000	1	57.780	1.823
320.000	160.000	1	67.641	2.031
332.000	154.000	1	85.869	1.962
344.000	148.000	1	77.584	1.877
356.000	142.000	1	69.950	1.815
368.000	136.000	1	62.968	1.828
380.000	130.000	1	61.347	2.437

AT POINT (356.000, 142.000),RADIUS 69.950
THE MINIMUM FACTOR OF SAFETY IS 1.815

356.000	142.000	1	69.950	1.815
366.000	142.000	1	67.874	1.839
346.000	142.000	1	71.556	1.875
356.000	152.000	1	80.262	1.811
356.000	162.000	1	90.590	1.809
356.000	172.000	1	100.933	1.807

356.000	182.000	1	111.293	1.806
356.000	192.000	1	121.668	1.806
356.000	202.000	1	132.059	1.805
356.000	212.000	1	142.221	1.805
356.000	222.000	1	153.001	1.805
356.000	232.000	1	162.822	1.805
366.000	222.000	1	151.843	1.812
346.000	222.000	1	154.115	1.814
358.500	222.000	1	152.413	1.805
353.500	222.000	1	152.676	1.806
356.000	224.500	1	155.221	1.805
356.000	227.000	1	158.379	1.805
358.500	224.500	1	155.553	1.805
353.500	224.500	1	155.862	1.806

AT POINT (356.000, 224.500),RADIUS 155.221
THE MINIMUM FACTOR OF SAFETY IS 1.805

PSR Marine Sediment   2.5:1 Slope   seismic g=0.1   PSR25s.IN

CASE NUMBER 1
Summary of Lowest Factors of Safety

Coordinates (x,y)		Seepage Cond	Radius	Factor of Safety
200.000	160.000	1	22.386	1.791
212.000	154.000	1	22.637	1.902
224.000	148.000	1	21.305	1.915
236.000	142.000	1	19.974	1.930
248.000	136.000	1	18.643	1.948
260.000	130.000	1	17.312	1.968
224.000	160.000	1	32.485	1.738
236.000	154.000	1	31.154	1.739
248.000	148.000	1	29.823	1.741
260.000	142.000	1	28.491	1.743
272.000	136.000	1	27.160	1.745
284.000	130.000	1	25.829	1.747
248.000	160.000	1	41.003	1.656
260.000	154.000	1	39.671	1.654
272.000	148.000	1	38.340	1.653
284.000	142.000	1	37.009	1.651
296.000	136.000	1	35.677	1.649
308.000	130.000	1	35.458	1.693
272.000	160.000	1	49.520	1.605
284.000	154.000	1	48.188	1.602
296.000	148.000	1	46.857	1.599
308.000	142.000	1	46.648	1.631
320.000	136.000	1	45.262	1.628
332.000	130.000	1	43.876	1.624
296.000	160.000	1	58.037	1.569
308.000	154.000	1	57.837	1.595
320.000	148.000	1	56.451	1.591
332.000	142.000	1	55.066	1.587
344.000	136.000	1	64.333	1.506
356.000	130.000	1	57.780	1.426
320.000	160.000	1	67.641	1.567
332.000	154.000	1	83.804	1.549
344.000	148.000	1	76.606	1.476
356.000	142.000	1	69.950	1.417
368.000	136.000	1	62.968	1.410
380.000	130.000	1	61.347	1.771

AT POINT (368.000, 136.000),RADIUS 62.968
THE MINIMUM FACTOR OF SAFETY IS 1.410

368.000	136.000	1	62.968	1.410
378.000	136.000	1	66.434	1.621
358.000	136.000	1	63.144	1.413
368.000	146.000	1	72.300	1.417
368.000	126.000	1	53.635	1.422
370.500	136.000	1	63.834	1.432

365.500	136.000	1	62.101	1.411
368.000	138.500	1	65.301	1.410
368.000	141.000	1	67.634	1.411
370.500	138.500	1	66.168	1.427
365.500	138.500	1	64.434	1.416

AT POINT (368.000, 138.500),RADIUS 65.301
THE MINIMUM FACTOR OF SAFETY IS 1.410

APPENDIX D

DREDGING DEPTHS

Contamination Depth Estimates

Station	Area (sqft)	Depth (ft bgs) to CSL	Depth (ft bgs) to SQS
EB001	21634	16	20
EB002	19879	16	20
EB003	18658	4	4
EB004	11575	4	8
EB005	16630	4	8
EB006	18764	4	4
EB007	11174	0	0
EB008	25691	4	4
EB009	15931	16	20
EB010	15850	0	0
EB011	20137	4	4
EB012	20318	16	20
EB013	24709	16	20
EB014	19711	4	4
EB015	26619	4	8
EB016	25726	16	20
EB017	23994	4	12
EB018	22159	16	20
EB019	21199	4	12
EB020	25251	8	12
EB021	22993	12	16
EB022	31788	12	16
EB023	17741	16	16
EB024	24141	4	4
EB025	16292	4	8
EB026	46007	12	12
EB027	33522	20	>20
EB028	25691	0	0
EB029	28687	4	4
EB030	21903	4	8
EB031	22539	4	8
EB032	34899	8	12
EB033	30386	4	8
EB034	33742	4	8
EB035	42349	4	8
EB036	24466	4	4
EB037	33277	4	8
EB038	27461	4	8
EB039	31210	4	4
EB040	30137	4	4
EB041	51746	4	8
EB042	44555	4	4
EB043	44273	0	0
EB045	37466	4	8
EB047	57467	0	0
EB049	30278	12	12
EB052	118386	0	0
EB054	41361	8	8
EB056	59935	4	4
EB057	85626	4	4
EB060	46088	4	8
EB061	47359	4	4
EB062	40328	4	8
EB063	54860	4	4

Station	Area (sqft)	Depth (ft bgs) to CSL	Depth (ft bgs) to SQS
EB066	52010	12	16
EB067	54124	4	8
EB072	59128	4	8
EB073	66083	4	4
EB077	36480	4	8
EB078	62555	4	4
EB080	57435	4	4
EB082	61335	4	4
EB084	35748	4	4
EB085	47390	4	4
EB086	54775	4	4
EB087	51657	4	4
EB088	42798	4	4
EB089	42276	4	4
EB091	52804	4	4
EB094	75733	0	0
EB095	66088	4	4
EB096	71742	4	4
EB097	102635	4	4
EB098	65389	4	4
EB099	72800	4	4
EB100	82863	4	4
EB101	47596	4	4
EB102	48974	4	4
EB103	60868	4	4
EB104	25919	4	4
EB105	27847	4	4
EB106	18211	16	20
EB107	82750	0	0
EB108	193807	0	0
EB109	155607	0	0
EB113	33087	16	20
EB116	32186	4	8
EB117	63055	4	4
EB118	88250	0	0
EB119	55331	4	4
EB120	96258	0	0
EB121	46775	4	4
EB122	61973	4	4
EB123	68535	4	4
EB124	89074	4	4
EB125	106902	0	0
EB126	85265	4	4
EB127	102665	4	4
EB128	129554	4	4
EB129	110182	4	4
EB130	56449	0	0
EB131	47635	0	0
EB132	90601	0	0
EB133	99900	0	0
EB135	67836	0	0
EB136	87126	4	4
EB137	122051	4	4
EB144	71270	4	4

APPENDIX E

ALTERNATIVE SCHEDULES

PSR FS SCHEDULE ASSUMPTIONS

Capping overall duration was based on cap material availability and assumed 100 percent of available material could be used for PSR.

Hydraulic dredging durations were based on a production rate at approximately 4,000 cubic yards per day. Clamshell dredging durations were based on 2,000 cubic yards per day.

Capping the area near the shoreline was assumed to be accomplished using a clamshell dredge. Capping rate was assumed to be 1000 cubic yards per day.

No in-water work was assumed to occur during the fish window of April 1 to June 15.

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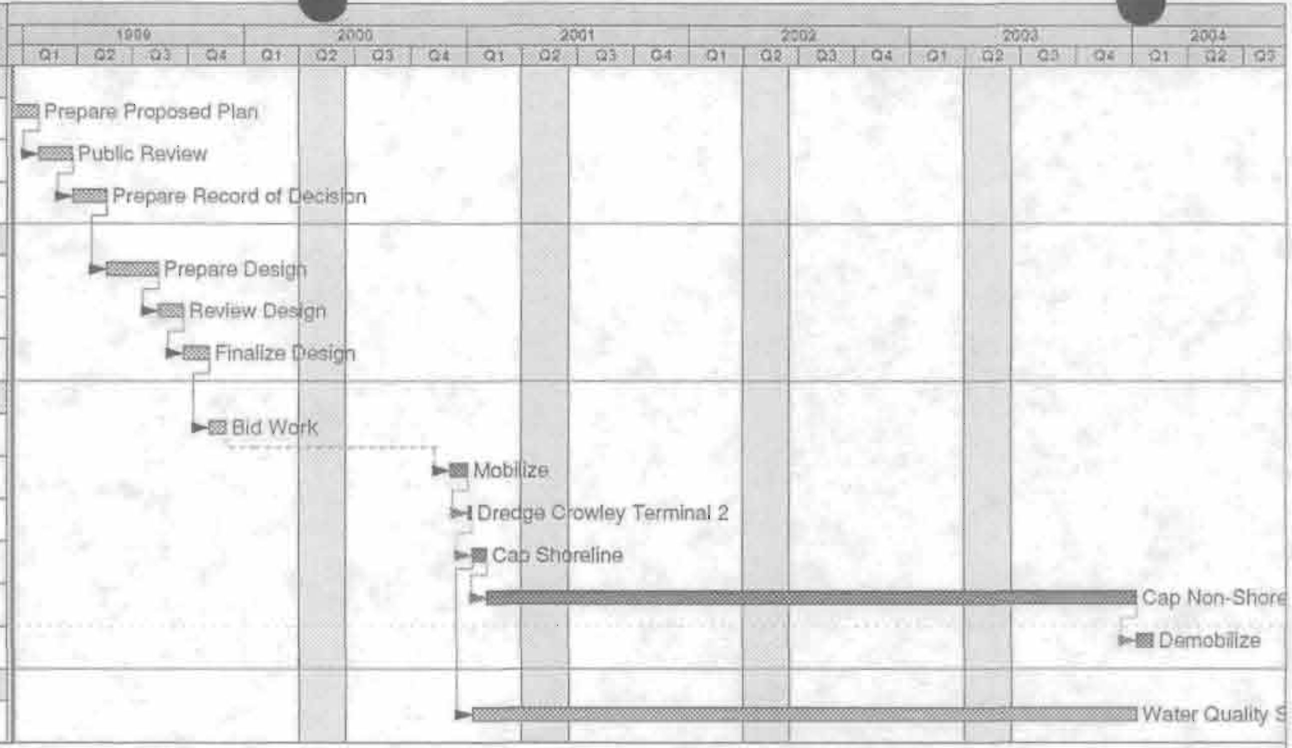
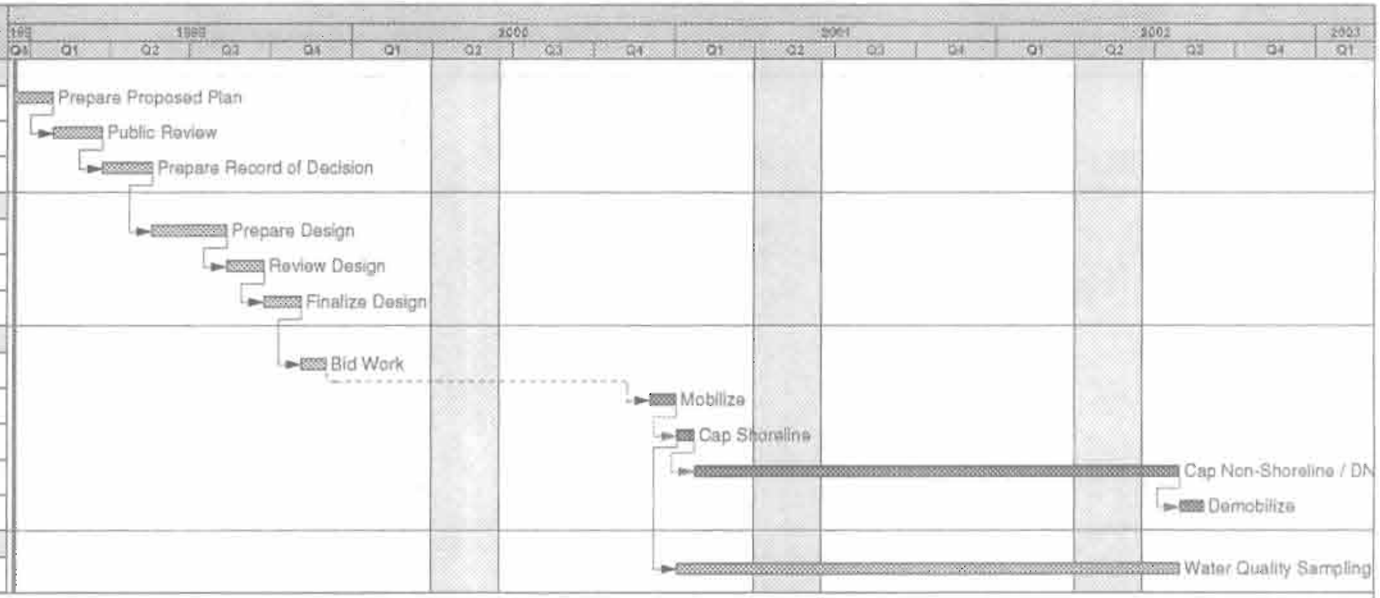
Description	Orig Dur	Early Start	Early Finish
Administration			
Prepare Proposed Plan	30d	15DEC98	27JAN99
Public Review	40d	28JAN99	24MAR99
Prepare Record of Decision	40d	24MAR99	19MAY99
Design			
Prepare Design	60d	19MAY99	12AUG99
Review Design	30d	12AUG99	23SEP99
Finalize Design	30d	23SEP99	04NOV99
Construction			
Bid Work	20d	04NOV99	02DEC99
Mobilize	20d	04DEC00 *	02JAN01
Dredge Crowley Terminal 2	4d	03JAN01	08JAN01
Cap Shoreline	18d	09JAN01	01FEB01
Cap Non-Shoreline / DNAPL	590d6h	02FEB01	07JAN04
Demobilize	20d	07JAN04	04FEB04
Sampling			
Water Quality Sampling	609d	09JAN01	07JAN04



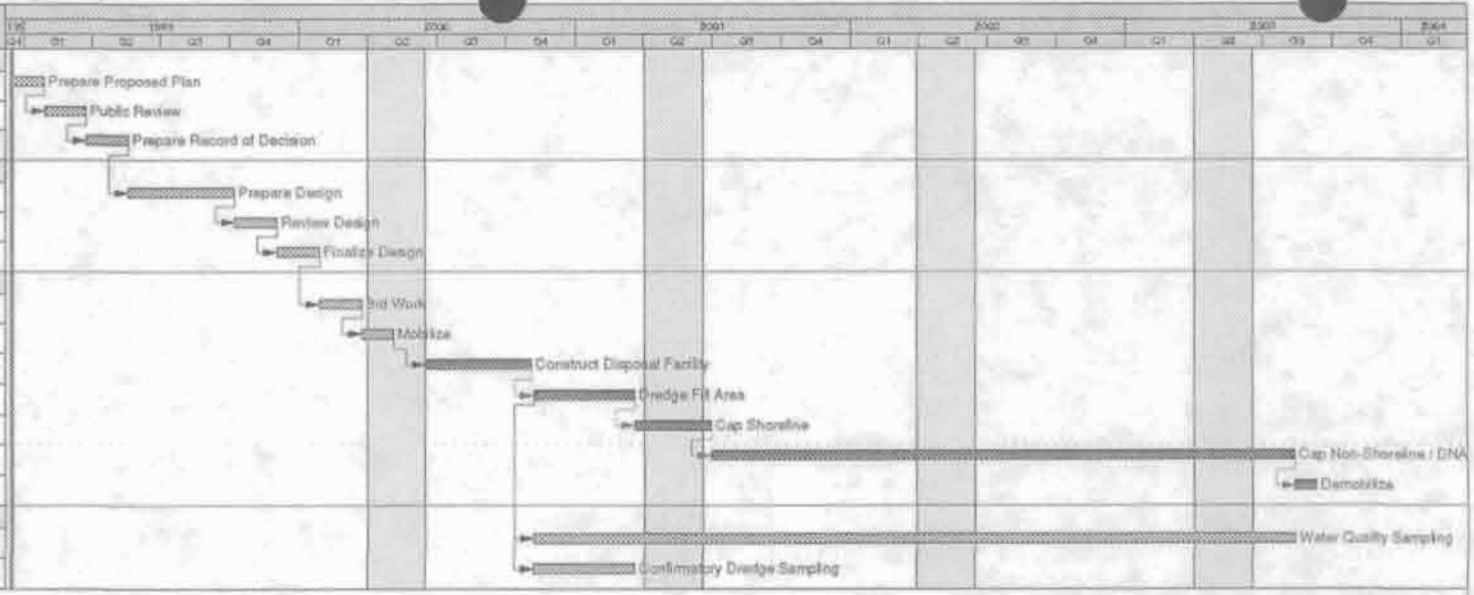
Alternative 3a - Capping to SQS

Description	Orig Dur	Early Start	Early Finish
Administration			
Prepare Proposed Plan	30d	15DEC98	27JAN99
Public Review	40d	28JAN99	24MAR99
Prepare Record of Decision	40d	24MAR99	19MAY99
Design			
Prepare Design	60d	19MAY99	12AUG99
Review Design	30d	12AUG99	23SEP99
Finalize Design	30d	23SEP99	04NOV99
Construction			
Bid Work	20d	04NOV99	02DEC99
Mobilize	20d	04DEC00 *	02JAN01
Cap Shoreline	14d	03JAN01	22JAN01
Cap Non-Shoreline / DNAPL	281d	23JAN01	29JUL02
Demobilize	20d	30JUL02	26AUG02
Sampling			
Water Quality Sampling	295d	03JAN01	29JUL02



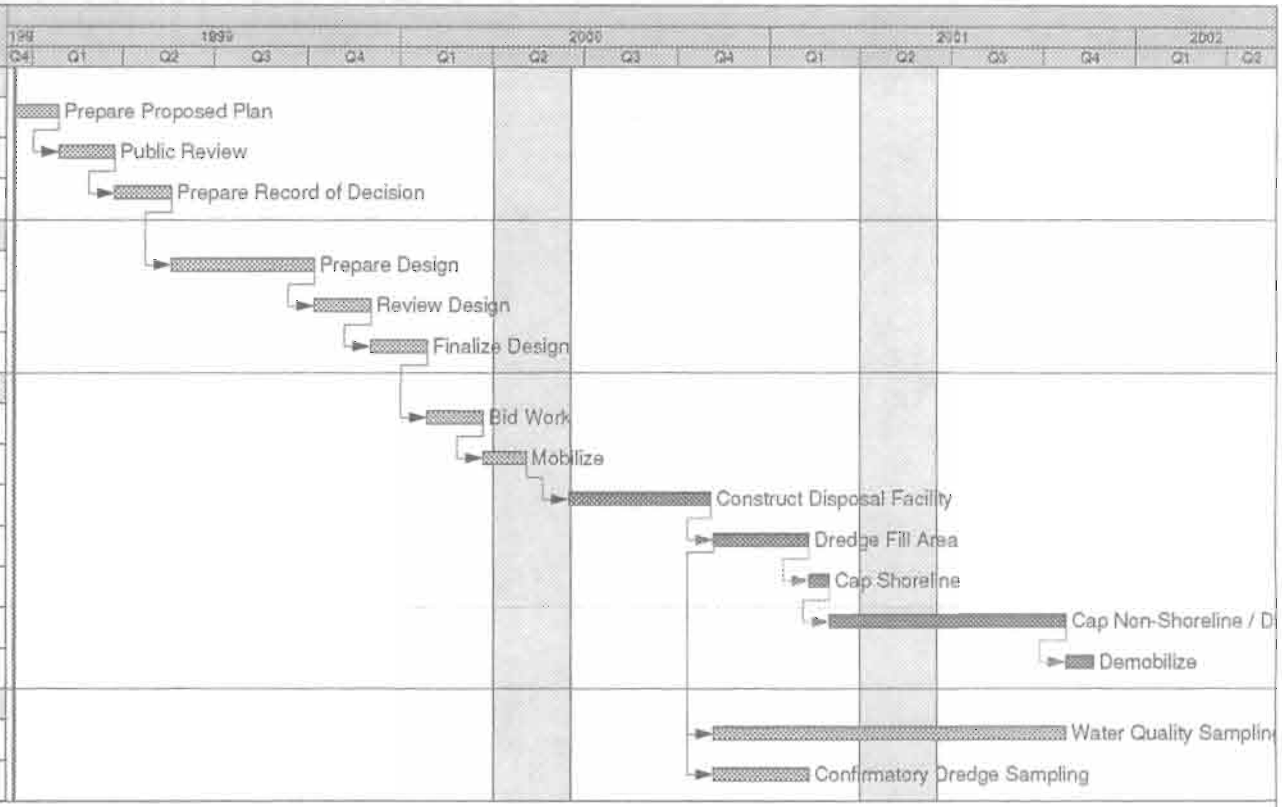
Alternative 3b - Capping to CSLs

Description	Orig Dur	Early Start	Early Finish
Administration			
Prepare Proposed Plan	30d	15DEC98	27JAN99
Public Review	40d	25JAN99	24MAR99
Prepare Record of Decision	40d	24MAR99	19MAY99
Design			
Prepare Design	100d	19MAY99	07OCT99
Review Design	40d	07OCT99	02DEC99
Finalize Design	40d	02DEC99	27JAN00
Construction			
Bid Work	40d	27JAN00	23MAR00
Mobilize	30d	23MAR00	04MAY00
Construct Disposal Facility	100d	16JUN00	03NOV00
Dredge Fill Area	94d3h	06NOV00	20MAR01
Cap Shoreline	18d	20MAR01	29JUN01
Cap Non-Shoreline / DNAPL	436d7h	29JUN01	13AUG03
Demobilize	20d	13AUG03	10SEP03
Sampling			
Water Quality Sampling	550d	06NOV00	13AUG03
Confirmatory Dredge Sampling	85d	06NOV00	20MAR01



Alternative 4a - Fill Removal to SQS and Capping

Description	Orig Dur	Early Start	Early Finish
Administration			
Prepare Proposed Plan	30d	15DEC98	27JAN99
Public Review	40d	28JAN99	24MAR99
Prepare Record of Decision	40d	24MAR99	19MAY99
Design			
Prepare Design	100d	19MAY99	07OCT99
Review Design	40d	07OCT99	02DEC99
Finalize Design	40d	02DEC99	27JAN00
Construction			
Bid Work	40d	27JAN00	23MAR00
Mobilize	30d	23MAR00	04MAY00
Construct Disposal Facility	100d	16JUN00	03NOV00
Dredge Fill Area	67d4h	06NOV00	09FEB01
Cap Shoreline	14d	09FEB01	01MAR01
Cap Non-Shoreline / DNAPL	112d2h	01MAR01	23OCT01
Demobilize	20d	23OCT01	20NOV01
Sampling			
Water Quality Sampling	194d	06NOV00	23OCT01
Confirmatory Dredge Sampling	68d	06NOV00	09FEB01



Alternative 4b - Fill Removal to CSLs and Capping

APPENDIX F

COST ESTIMATE DETAILS

APPENDIX F

COST ESTIMATE DETAILS

LIST OF TABLES

LIST OF TABLES (*Continued*)

LIST OF TABLES (*Continued*)

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Table F-1a—Alternative 2 Dredge to CSLs
Total Cost Estimate

Description	Unit	Quantity	Unit Cost	Cost
1. Dredging				
A. Dredging				
Dredging Mobilization/Demobilization	LS	1	300,000.00	$300,000
Volume (100% hydraulic)	CY	372000	3.00	$1,116,000
Transport and Placement (Pipeline)	CY	372000	1.50	$558,000
Post-Remediation Confirm. Sampling (Table F-1e)	LS	1	10,800.00	$10,800
B. Short-term Monitoring - Dredging				
Water Quality Monitoring (Table F-1b)	LS	1	169,410.00	$169,410
Bathymetric/Sed. Profile Surveys	LS	1	11,500.00	$11,500
2. Groundwater Discharge Area Capping				
A. Cap				
Silty Sand	CY	20000	3.00	$60,000
Transport and Placement	CY	20000	4.25	$85,000
B. Short-term Monitoring - Capping				
Water Quality Monitoring (Table F-1c)	LS	1	3,720.00	$3,720
Bathymetric/Sed. Profile Surveys	LS	1	11,500.00	$11,500
3. Shoreline Area Capping				
A. Cap				
Silty Sand	CY	16000	3.00	$48,000
Transport and Placement	CY	16000	9.00	$144,000
B. Short-term Monitoring - Capping				
Water Quality Monitoring (Table F-1d)	LS	1	38,212.00	$38,212
Bathymetric/Sed. Profile Surveys	LS	1	11,500.00	$11,500
4. Offshore Area Capping				
A. Cap				
Silty Sand	CY	71000	3.00	$213,000
Transport and Placement	CY	71000	4.25	$301,750
B. Short-term Monitoring - Capping				
Water Quality Monitoring	LS	1	14,300.00	$14,300
Bathymetric/Sed. Profile Surveys	LS	1	11,500.00	$11,500
5. Long-Term Monitoring				
A. Capped Areas (Table F-1f)	1 per 2 Years	30	37,800.00	$531,686
B. Dredged Areas (Table F-1g)	1 per 5 Years	30	29,700.00	$196,801
6 Cap Maintenance	3% per Year	30	25,552.50	$718,831
		SUBTOTAL		$4,555,511
Administrative Cost	% SUBTOTAL	10 *		$455,551
Engineering Expenses	% SUBTOTAL	15 *		$683,327
Contingency Allowances	% SUBTOTAL	25 *		$1,138,878
TOTAL PRESENT WORTH VALUE				$6,833,000

The cost of this alternative is highly subject to change based on results from future preremedial design investigations. This is provided as a relative measure from which to compare the costs of different alternatives.
* Based on best professional judgement.

Table F-1b—Alternative 2 Short-Term Dredging Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	42	1000	$42,000
labor	Day	42	1000	$42,000
navigation	Day	42	100	$4,200
chemist	Day	42	750	$31,500
Initial Analytical				
test kits	Each	432	40	$17,280
lab samples	Each	22	150	$3,300
Follow-on Analytical				
test kits	Each	612	40	$24,480
lab samples	Each	31	150	$4,650
Total Cost				$169,410

Based on: 85 days of follow-on dredging in addition to the initial 8 sampling days.

Table F-1c—Alternative 2 Groundwater Discharge Area Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	0	400	$0
boat rental	Day	1	1000	$1,000
labor	Day	1	1000	$1,000
navigation	Day	1	100	$100
chemist	Day	1	750	$750
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	18	40	$720
lab samples	Each	1	150	$150
Total Cost				$3,720

Based on: 5 days of capping immediately after shoreline area

Table F-1d—Alternative 2 Shoreline Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	10	1000	$10,000
labor	Day	10	1000	$10,000
navigation	Day	10	100	$1,000
chemist	Day	10	750	$7,500
Initial Analytical				
test kits	Each	144	40	$5,760
lab samples	Each	7	150	$1,050
Follow-on Analytical				
test kits	Each	29	40	$1,152
lab samples	Each	1	150	$150
Total Cost				$38,212

Based on: 8 days of follow-on capping in addition to the initial 8 sampling days

Table F-1e—Alternative 2 Post-Dredging Confirmation Sampling Detailed Cost Assumptions

Item	Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor					
	mob/demob	Day	4	400	$1,600
	boat rental	Day	2	1000	$2,000
	labor	Day	2	1500	$3,000
	navigation	Day	2	400	$800
Analytical					
	lab samples	Each	17	200	$3,400
Total Cost					$10,800

Based on: 33 acres dredged
17 samples
2 sampling days

Table F-1f—Alternative 2 Long-Term Capping Monitoring
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	2	2800	$5,600
boat labor	Day	2	1000	$2,000
navigation	Day	2	800	$1,600
core process labor	Day	2	1500	$3,000
reporting	Week	6	2000	$12,000
Analytical				
lab samples	Each	10	200	$2,000
bioassays	Each	5	2000	$10,000
Total Cost				$37,800

Based on: 14 acres capped
5 stations
2 sampling days

Table F-1g—Alternative 2 Long-Term Dredged Area Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	1	1000	$1,000
boat labor	Day	1	1500	$1,500
navigation	Day	1	400	$400
reporting	Week	6	2000	$12,000
Analytical				
lab samples	Each	6	200	$1,200
bioassays	Each	6	2000	$12,000
Total Cost				$29,700

Based on: 33 acres dredged
6 stations
1.0 sampling days

Table F-2a—Alternative 3a Capping to SQS
Total Cost Estimate

Description	Unit	Quantity	Unit Cost	Cost
1. Mobilization	LS	1	300,000.00	$300,000
2. Crowley Marine Terminal Dredging				
Dredge Mobilization	LS	1	35,000.00	$35,000
Volume (100% clamshell)	CY	3,500	6.00	$21,000
Placement north of terminal	CY	3,500	4.00	$14,000
Short Term Monitoring	LS	1	20,000	$20,000
3. Groundwater Discharge Area Capping				
A. Cap				
Silty Sand	CY	20000	3.00	$60,000
Transport and Placement	CY	20000	4.25	$85,000
B. Short-term Monitoring - Capping				
Water Quality Monitoring (Table F-2c)	LS	1	3,720.00	$3,720
Bathymetric/Sed. Profile Surveys	LS	1	11,700.00	$11,700
4. Shoreline Area Capping				
A. Cap				
Silty Sand	CY	18000	3.00	$54,000
Transport and Placement	CY	18000	9.00	$162,000
B. Short-term Monitoring - Capping				
Water Quality Monitoring (Table F-2b)	LS	1	38,650.00	$38,650
Bathymetric/Sed. Profile Surveys	LS	1	11,700.00	$11,700
5. Offshore Area Capping				
A. Cap				
Silty Sand	CY	740000	3.00	$2,220,000
Transport and Placement	CY	740000	4.25	$3,145,000
B. Short-term Monitoring - Capping				
Water Quality Monitoring (Table F-2d)	LS	1	138,640.00	$138,640
Bathymetric/Sed. Profile Surveys	LS	1	11,700.00	$11,700
6. Long Term Monitoring - Capped Areas (Table F-2e)	1 per 2 Years	30	139,200.00	$1,957,956
7. Cap Maintenance	1% per Year	30	57,260.00	$1,610,812
		SUBTOTAL		$9,900,878
Administrative Cost	% SUBTOTAL	10 *		$990,088
Engineering Expenses	% SUBTOTAL	15 *		$1,485,132
Contingency Allowances	% SUBTOTAL	25 *		$2,475,220
TOTAL PRESENT WORTH VALUE				**$14,851,000**

The cost of this alternative is highly subject to change based on results from future preremedial design investigations. This is provided as a relative measure from which to compare the costs of different alternatives.

* Based on best professional judgement.

Table F-2b—Alternative 3a Shoreline Area Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	10	1000	$10,000
labor	Day	10	1000	$10,000
navigation	Day	10	100	$1,000
chemist	Day	10	750	$7,500
Initial Analytical				
test kits	Each	144	40	$5,760
lab samples	Each	7	150	$1,050
Follow-on Analytical				
test kits	Each	36	40	$1,440
lab samples	Each	2	150	$300
Total Cost				$38,650

Based on: 10 days of follow-on capping in addition to the initial 8 sampling days.

Table F-2c—Alternative 3a Groundwater Discharge Area Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	0	400	$0
boat rental	Day	1	1000	$1,000
labor	Day	1	1000	$1,000
navigation	Day	1	100	$100
chemist	Day	1	750	$750
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	18	40	$720
lab samples	Each	1	150	$150
Total Cost				$3,720

Based on: 5 days of capping immediately after shoreline area.

Table F-2d—Alternative 3a Offshore Short-Term Capping Monitoring
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	37	1000	$37,000
labor	Day	37	1000	$37,000
navigation	Day	37	100	$3,700
chemist	Day	37	750	$27,750
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	666	40	$26,640
lab samples	Each	33	150	$4,950
Total Cost				$138,640

Based on: 185 days of capping immediately after shoreline area.

Table F-2e—Alternative 3a Long-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	8	2800	$22,400
boat labor	Day	8	1000	$8,000
navigation	Day	8	800	$6,400
core process labor	Day	8	1500	$12,000
reporting	Week	6	2000	$12,000
Analytical				
lab samples	Each	64	200	$12,800
bioassays	Each	32	2000	$64,000
Total Cost				$139,200

Based on: 96 acres capped
32 stations
8 sampling days

Table F-3a—Alternative 3b Capping to CSLs
Total Cost Estimate

Description	Unit	Quantity	Unit Cost	Cost
1. Mobilization	LS	1	300,000.00	$300,000
2. Crowley Marine Terminal Dredging				
Dredge Mobilization	LS	1	35,000.00	$35,000
Volume (100% clamshell)	CY	3,500	6.00	$21,000
Placement north of terminal	CY	3,500	4.00	$14,000
Short Term Monitoring	LS	1	20,000	$20,000
3. Groundwater Discharge Area Capping				
A. Cap				
Silty Sand	CY	20,000	3.00	$60,000
Transport and Placement	CY	20,000	4.25	$85,000
B. Short-term Monitoring - Capping				
Water Quality Monitoring (Table F-3c)	LS	1	3,720.00	$3,720
Bathymetric/Sed. Profile Surveys	LS	1	11,700.00	$11,700
4. Shoreline Area Capping				
A. Cap				
Silty Sand	CY	15,000	3.00	$45,000
Transport and Placement	CY	15,000	9.00	$135,000
B. Short-term Monitoring - Capping				
Water Quality Monitoring (Table F-3b)	LS	1	38,068.00	$38,068
Bathymetric/Sed. Profile Surveys	LS	1	11,700.00	$11,700
5. Offshore Area Capping				
A. Cap				
Silty Sand	CY	328,000	3.00	$984,000
Transport and Placement	CY	328,000	4.25	$1,394,000
B. Short-term Monitoring - Capping				
Water Quality Monitoring (Table F-3d)	LS	1	61,258.00	$61,258
Bathymetric/Sed. Profile Surveys	LS	1	11,700.00	$11,700
6. Long Term Monitoring - Capped Areas	1 per 2 Years	30	76,400.00	$1,074,625
(Table F-3e)				
6. Cap Maintenance	1% per Year	30	27,030.00	$760,396
		SUBTOTAL		$5,066,167
Administrative Cost	% SUBTOTAL	10 *		$506,617
Engineering Expenses	% SUBTOTAL	15 *		$759,925
Contingency Allowances	% SUBTOTAL	25 *		$1,266,542
TOTAL PRESENT WORTH VALUE				**$7,599,000**

The cost of this alternative is highly subject to change based on results from future preremedial design investigations. This is provided as a relative measure from which to compare the costs of different alternatives.
* Based on best professional judgement.

Table F-3b—Alternative 3b Shoreline Area Short-Term Capping Monitoring Detailed Cost Estimate

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	10	1000	$10,000
labor	Day	10	1000	$10,000
navigation	Day	10	100	$1,000
chemist	Day	10	750	$7,500
Initial Analytical				
test kits	Each	144	40	$5,760
lab samples	Each	7	150	$1,050
Follow-on Analytical				
test kits	Each	25.2	40	$1,008
lab samples	Each	1	150	$150
Total Cost				$38,068

Based on: 7 days of follow-on capping in addition to the initial 8 sampling days.

Table F-3c—Alternative 3b Groundwater Discharge Area Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	0	400	$0
boat rental	Day	1	1000	$1,000
labor	Day	1	1000	$1,000
navigation	Day	1	100	$100
chemist	Day	1	750	$750
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	18	40	$720
lab samples	Each	1	150	$150
Total Cost				$3,720

Based on: 5 days of capping immediately after shoreline area.

Table F-3d—Alternative 3b Offshore Short-Term Capping Monitoring
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	16	1000	$16,000
labor	Day	16	1000	$16,000
navigation	Day	16	100	$1,600
chemist	Day	16	750	$12,000
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	295	40	$11,808
lab samples	Each	15	150	$2,250
Total Cost				$61,258

Based on: 82 days of capping immediately after shoreline area.

Table F-3e—Alternative 3b Long-Term Cap Monitoring
Detailed Cost Estimate

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	4	2800	$11,200
boat labor	Day	4	1000	$4,000
navigation	Day	4	800	$3,200
core process labor	Day	4	1500	$6,000
reporting	Week	6	2000	$12,000
Analytical				
lab samples	Each	32	200	$6,400
bioassays	Each	16	2000	$32,000
Total Cost				$76,400

Based on: 47 acres capped
16 stations
4 sampling days

Table F-4a— Alternative 4a Fill Removal to SQS and Cap
Total Cost Estimate

Description	Unit	Quantity	Unit Cost	Cost
1. Dredging				
A. Dredging				
Dredging Mobilization/Demobilization	LS	1	300,000.00	$300,000
Volume (100% hydraulic)	CY	381,500	3.00	$1,144,500
Transport and Placement (Pipeline)	CY	381,500	1.50	$572,250
Post Remediation Confirm. Sampling	LS	1	9,800	$9,800
(Table F-4f)				
B. Short-term Monitoring - Dredging				
Water Quality Monitoring (Table F-4b)	LS	1	172,266.00	$172,266
Bathymetric/Sed. Profile Surveys	LS	1	8,750.00	$8,750
2. Groundwater Discharge Area Capping				
A. Cap				
Silty Sand	CY	20,000	3.00	$60,000
Transport and Placement	CY	20,000	4.25	$85,000
B. Short-term Monitoring				
Water Quality Monitoring (Table F-4d)	LS	1	3,720	$3,720
Bathymetric/Sed. Profile Surveys	LS	1	8,750	$8,750
3. Shoreline Area Capping				
A. Cap				
Silty Sand	CY	18,000	3.00	$54,000
Transport and Placement (clamshell)	CY	18,000	9.00	$162,000
B. Short-term Monitoring				
Water Quality Monitoring (Table F-4e)	LS	1	38,650	$38,650
Bathymetric/Sed. Profile Surveys	LS	1	8,750	$8,750
4. Offshore Area Capping				
A. Cap				
Silty Sand	CY	531,000	3.00	$1,593,000
Transport and Placement	CY	531,000	4.25	$2,256,750
B. Short-term Monitoring				
Water Quality Monitoring (Table F-4e)	LS	1	100,162	$100,162
Bathymetric/Sed. Profile Surveys	LS	1	8,750	$8,750
5 Long-term Monitoring				
A. Capped Areas (Table F-4g)	1 per 2 Years	30	116,300	$1,635,849
B. Dredged Areas (Table F-4h)	1 per 5 Years	30	25,300	$167,646
6 Cap Maintenance	1% per Year	30	42,108	$1,184,549
		SUBTOTAL		$9,575,142
Administrative Cost	% SUBTOTAL	10 *		$957,514
Engineering Expenses	% SUBTOTAL	15 *		$1,436,271
Contingency Allowances	% SUBTOTAL	25 *		$2,393,786
TOTAL PRESENT WORTH VALUE				$14,363,000

The cost of this alternative is highly subject to change based on results from future preremedial design investigations. This is provided as a relative measure from which to compare the costs of different alternatives.
* Based on best professional judgement.

Table F-4b—Alternative 4a Short-Term Dredging Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	43	1000	$42,800
labor	Day	43	1000	$42,800
navigation	Day	43	100	$4,280
chemist	Day	43	750	$32,100
Initial Analytical				
test kits	Each	432	40	$17,280
lab samples	Each	22	150	$3,300
Follow-on Analytical				
test kits	Each	626	40	$25,056
lab samples	Each	31	150	$4,650
Total Cost				$172,266

Based on: 87 days of follow-on dredging in addition to the initial 8 sampling days.

Table F-4c—Alternative 4a Shoreline Area Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	10	1000	$10,000
labor	Day	10	1000	$10,000
navigation	Day	10	100	$1,000
chemist	Day	10	750	$7,500
Initial Analytical				
test kits	Each	144	40	$5,760
lab samples	Each	7	150	$1,050
Follow-on Analytical				
test kits	Each	36	40	$1,440
lab samples	Each	2	150	$300
Total Cost				$38,650

Based on: 10 days of follow-on capping in addition to the initial 8 sampling days.

Table F-4d—Alternative 4a Groundwater Discharge Area Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	0	400	$0
boat rental	Day	1	1000	$1,000
labor	Day	1	1000	$1,000
navigation	Day	1	100	$100
chemist	Day	1	750	$750
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	18	40	$720
lab samples	Each	1	150	$150
Total Cost				$3,720

Based on: 5 days of capping immediately after shoreline area.

Table F-4e—Alternative 4a Offshore Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	26.6	1000	$26,600
labor	Day	26.6	1000	$26,600
navigation	Day	26.6	100	$2,660
chemist	Day	26.6	750	$19,950
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	478.8	40	$19,152
lab samples	Each	24	150	$3,600
Total Cost				$100,162

Based on: 133 days of capping immediately after shoreline area.

Table F-4f—Alternative 4a Post-Dredging Confirmation Sampling Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	2	1000	$2,000
labor	Day	2	1500	$3,000
navigation	Day	2	400	$800
Analytical				
lab samples	Each	12	200	$2,400
Total Cost				$9,800

Based on: 24 acres dredged
12 samples
2 sampling days

Table F-4g—Alternative 4a Long-Term Capping Monitoring
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	7	2800	$19,600
boat labor	Day	7	1000	$7,000
navigation	Day	7	800	$5,600
core process labor	Day	7	1500	$10,500
reporting	Week	6	2000	$12,000
Analytical				
lab samples	Each	50	200	$10,000
bioassays	Each	25	2000	$50,000
Total Cost				$116,300

Based on: 74 acres capped
25 stations
7 sampling days

Table F-4h—Alternative 4a Long-Term Dredged Area Monitoring
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	1	1000	$1,000
boat labor	Day	1	1500	$1,500
navigation	Day	1	400	$400
reporting	Week	6	2000	$12,000
Analytical				
lab samples	Each	4	200	$800
bioassays	Each	4	2000	$8,000
Total Cost				$25,300

Based on: 24 acres dredged
4 stations
1.0 sampling days

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Table F-5a— Alternative 4b Fill Removal to CSLs and Cap
Total Cost Estimate

Description	Unit	Quantity	Unit Cost	Cost
1. Dredging				
A. Dredging				
Dredging Mobilization/Demobilization	LS	1	300,000.00	$300,000
Volume (100% hydraulic)	CY	273,500	3.00	$820,500
Transport and Placement (Pipeline)	CY	273,500	1.50	$410,250
Post Remediation Confirm. Sampling	LS	1	9,800.00	$9,800
(Table F-5f)				
B. Short-term Monitoring - Dredging				
Water Quality Monitoring (Table F-5b)	LS	1	132,360.00	$132,360
Bathymetric/Sed. Profile Surveys	LS	1	8,750.00	$8,750
2. Groundwater Discharge Area Capping				
A. Cap				
Silty Sand	CY	20,000	3.00	$60,000
Transport and Placement	CY	20,000	4.25	$85,000
B. Short-term Monitoring				
Water Quality Monitoring (Table F-5d)	LS	1	3,720.00	$3,720
Bathymetric/Sed. Profile Surveys	LS	1	8,750.00	$8,750
3. Shoreline Area Capping				
A. Cap				
Silty Sand	CY	15,000	3.00	$45,000
Transport and Placement (clamshell)	CY	15,000	9.00	$135,000
B. Short-term Monitoring				
Water Quality Monitoring (Table F-5a)	LS	1	38,068.00	$38,068
Bathymetric/Sed. Profile Surveys	LS	1	8,750.00	$8,750
4. Shoreline Area Capping				
A. Cap				
Silty Sand	CY	119,000	3.00	$357,000
Transport and Placement	CY	119,000	4.25	$505,750
B. Short-term Monitoring				
Water Quality Monitoring (Table F-5e)	LS	1	23,770.00	$23,770
Bathymetric/Sed. Profile Surveys	LS	1	8,750.00	$8,750
5 Long-term Monitoring				
A. Capped Areas (Table F-5g)	1 per 2 Years	30	45,000.00	$632,960
B. Dredged Areas (Table F-5h)	1 per 5 Years	30	26,100.00	$172,947
6 Cap Maintenance	1% per Year	30	11,877.50	$334,132
		SUBTOTAL		$4,101,257
Administrative Cost	% SUBTOTAL	10 *		$410,126
Engineering Expenses	% SUBTOTAL	15 *		$615,189
Contingency Allowances	% SUBTOTAL	25 *		$1,025,314
TOTAL PRESENT WORTH VALUE				$6,152,000

The cost of this alternative is highly subject to change based on results from future preremedial design investigations. This is provided as a relative measure from which to compare the costs of different alternatives.
* Based on best professional judgement.

Table F-5b—Alternative 4b Short-Term Dredging Monitoring
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	32	1000	$32,000
labor	Day	32	1000	$32,000
navigation	Day	32	100	$3,200
chemist	Day	32	750	$24,000
Initial Analytical				
test kits	Each	432	40	$17,280
lab samples	Each	22	150	$3,300
Follow-on Analytical				
test kits	Each	432	40	$17,280
lab samples	Each	22	150	$3,300
Total Cost				$132,360

Based on: 60 days of follow-on dredging in addition to the initial 8 sampling days.

Table F-5c—Alternative 4b Shoreline Area Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	10	1000	$10,000
labor	Day	10	1000	$10,000
navigation	Day	10	100	$1,000
chemist	Day	10	750	$7,500
Initial Analytical				
test kits	Each	144	40	$5,760
lab samples	Each	7	150	$1,050
Follow-on Analytical				
test kits	Each	25	40	$1,008
lab samples	Each	1	150	$150
Total Cost				$38,068

Based on: 7 days of follow-on capping in addition to the initial 8 sampling days.

Table F-5d—Alternative 4b Groundwater Discharge Area Short-Term Capping Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	0	400	$0
boat rental	Day	1	1000	$1,000
labor	Day	1	1000	$1,000
navigation	Day	1	100	$100
chemist	Day	1	750	$750
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	18	40	$720
lab samples	Each	1	150	$150
Total Cost				$3,720

Based on: 5 days of capping immediately after shoreline area.

Table F-5e—Alternative 4b Offshore Short-Term Capping Monitoring
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	6	1000	$6,000
labor	Day	6	1000	$6,000
navigation	Day	6	100	$600
chemist	Day	6	750	$4,500
Initial Analytical				
test kits	Each	0	40	$0
lab samples	Each	0	150	$0
Follow-on Analytical				
test kits	Each	108	40	$4,320
lab samples	Each	5	150	$750
Total Cost				$23,770

Based on: 30 days of capping immediately after shoreline area.

Table F-5f—Alternative 4b Post-Dredging Confirmation Sampling Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	2	1000	$2,000
labor	Day	2	1500	$3,000
navigation	Day	2	400	$800
Analytical				
lab samples	Each	12	200	$2,400
Total Cost				$9,800

Based on: 24 acres dredged
12 samples
2 sampling days

Table F-5g—Alternative 4b Long-Term Capping Monitoring
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	2	2800	$5,600
boat labor	Day	2	1000	$2,000
navigation	Day	2	800	$1,600
core process labor	Day	2	1500	$3,000
reporting	Week	6	2000	$12,000
Analytical				
lab samples	Each	16	200	$3,200
bioassays	Each	8	2000	$16,000
Total Cost				$45,000

Based on: 24 acres capped
8 stations
2 sampling days

Table F-5h—Alternative 4b Long-Term Dredged Area Monitoring Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Labor				
mob/demob	Day	4	400	$1,600
boat rental	Day	1	1000	$1,000
boat labor	Day	1	1500	$1,500
navigation	Day	1	400	$400
reporting	Week	6	2000	$12,000
Analytical				
lab samples	Each	8	200	$1,600
bioassays	Each	4	2000	$8,000
Total Cost				$26,100

Based on: 24 acres dredged
4 stations
1.0 sampling days

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Table F-6—Upland Disposal
Total Cost Estimate

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Land Purchase	Acres	25	75000	$1,875,000
Construction				
berm	CY	87,000	10	$870,000
double liner	Sq. Ft.	1,890,000	2	$3,780,000
leak detection system	LS	1	20000	$20,000
monitoring wells	Each	8	2000	$16,000
landfill cover liner	Sq. Ft.	1,000,000	0.8	$800,000
topsoil	CY	111,000	10	$1,110,000
hydro seeding	Acre	25	1000	$25,000
Sediment Disposal				
dewatering ponds	Each	2	250000	$500,000
loading	CY	350,000	1.5	$525,000
trucking	CY	350,000	6.4	$2,240,000
unload & place	CY	350,000	1.5	$525,000
bed liners	Each	12,000	30	$360,000
Incremental Costs				
dredging STM	Weeks	28.0	7500	$210,000
dredging standby	Days	140.0	2000	$280,000
Monitoring				
upland monitoring	Year	30.0	1900	$53,450
analytical	Year	30.0	1600	$45,010
reporting	Year	30	1800	$50,637
Subtotal				$13,285,097
Engineering	%	5	*	$664,255
Contingency	%	15	*	$1,992,765
TOTAL COST				**$15,942,000**

Note: Based on disposal of 350,000 CY of sediment. Unit disposal cost is $45 / C.Y.

* Based on best professional judgement.

Table F-7—CAD Disposal
Detailed Cost Assumptions

Item	Unit	No. of Units	Cost/ Unit	Total Cost
CAD Construction				
dredging	CY	350,000	3.5	$1,225,000
capping (via dredging)	CY	225,000	3.5	$787,500
Sediment Disposal				
barging to site	CY	350,000	0	$0
clamshell placement	CY	350,000	4	$1,400,000
Incremental Costs				
clamshell dredge	CY	350,000	2.5	$875,000
Dredging STM	Week	33	7500	$247,500
CAD Site LTM	1 / 2years	30	42600	$599,202
CAD Site Capping STM	Week	11	3700	$40,700
Subtotal				$5,174,902
Engineering	%	5	*	$258,745
Contingency	%	15	*	$776,235
TOTAL COST				**$6,210,000**

Note: Based on disposal of 350,000 CY of sediment. Unit disposal cost is $18 / C.Y.

* Based on best professional judgement.

Table F-8—Nearshore Disposal
Total Cost Estimate

Item	Unit	No. of Units	Cost/ Unit	Total Cost
Facility Construction				
berm	CY	124,000	25	$3,100,000
sand core	CY	83,000	14	$1,162,000
cover soil	CY	81,000	8	$648,000
asphalt	Sq. Yd.	48,400	10	$484,000
Habitat Enhancement				
sand, fish mix	CY	78,000	14	$1,092,000
misc. (logs, boulders, etc.)	LS	1	25000	$25,000
Sediment Disposal				
pumping to site	CY	300,000	0	$0
Decant Water Monitoring				
labor	Day	37	400	$14,800
analytical	Day	37	500	$18,500
Subtotal				$6,544,300
Engineering	%	15	*	$981,645
Contingency	%	25	*	$1,636,075
TOTAL COST				**$9,162,000**

Note: Based on disposal of 350,000 CY of sediment. Unit disposal cost is $26 / C.Y.

* Based on best professional judgement.

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APPENDIX G

COMPARATIVE ANALYSIS OF ALTERNATIVES

Table G-1—Alternative Ranking—Overall Protection of Human Health and the Environment

Alternative	Reduction of Human Health Risk	Reduction of Impacts to Benthos	Reduction of Impacts to Fish	Total
2	1.5	1	1	3.5
3a	5	5	5	15
3b	3	3	3	9
4a	4	4	4	12
4b	1.5	2	2	5.5

Higher score = greater protectiveness due to reduction in contaminant concentrations in sediment.
Tied ranks are averaged.

Table G-2—Alternative Ranking—Compliance with ARARs

Alternative	In Compliance	Total
2	3	3
3a	3	3
3b	3	3
4a	3	3
4b	3	3

All alternatives will meet ARARs, therefore they share the same score.

Table G-3—Alternative Ranking—Reduction in Toxicity, Mobility and Volume

Alternative	Reduction in Toxicity	Reduction in Mobility	Reduction in Volume	Total
2	0	3	0	3
3a	0	3	0	3
3b	0	3	0	3
4a	0	3	0	3
4b	0	3	0	3

No alternative reduces the toxicity or volume of contaminants in the environment, therefore they have a score of 0. All alternatives are able to reduce contaminant mobility through confinement, so they share the same score.

Table G-4—Alternative Ranking—Short-Term Effectiveness

Alternative	Human Biota Exposure	Worker Safety	Short-term WQ Impacts	Habitat Loss	Duration	Total
2	1.5	1.5	4	1.5	5	13.5
3a	4.5	4.5	1.5	4.5	1	16
3b	4.5	4.5	4	4.5	3	20.5
4a	1.5	1.5	1.5	1.5	2	8
4b	3	3	4	3	4	17

Higher scores = greater short-term effectiveness.
Tied ranks are averaged.

Table G-5—Alternative Ranking—Long-Term Effectiveness

Alternative	Reliability of Remedy	Monitoring Required	Maintenance Required	Adequacy of Institutional Controls	Total
2	4.5	5	5	3	17.5
3a	1.5	1	1	3	6.5
3b	1.5	3	3	3	10.5
4a	4.5	2	2	3	11.5
4b	3	4	4	3	14

Higher score = greater long-term effectiveness.
Tied ranks are averaged.
See section 5.5.5 For discussion of assumptions.

Table G-6—Alternative Ranking—Implementability

Alternative	Ease of Construction	Reliability of Technology	Monitoring Effectiveness	Capping Material Required	Requiring Disposal	Impact to Fisheries	Zone Required	Total
2	5	4.5	5	5	1.5	5	5	31
3a	1	1.5	1	1	4.5	1	1	11
3b	3	1.5	3	3	4.5	3	3	21
4a	2	4.5	2	2	1.5	2	2	16
4b	4	3	4	4	3	4	4	26

High score = greater implementability.
Tied ranks are averaged.
See section 5.5.6 for discussion of assumptions.

Table G-7—Alternative Ranking—Cost

Alternative	Cost
2	2
3a	4
3b	5
4a	1
4b	3

Highest score = least cost.
Costs only include removal and capping; disposal costs are not included with the exception of Alternatives 3a and 3b, because there are no additional disposal costs.

Table G-8—Disposal Option Ranking—Overall Protection of Human Health and the Environment

	Reduction of Impacts to Environment and Human Health	Total
Upland	2	2
Nearshore	2	2
CAD	2	2

Scores are shared because of the assumption that all disposal options are equally protective.

Table G-9—Disposal Option Ranking—Compliance with ARARs

	In Compliance	Total
Upland	2.5	2.5
Nearshore	2.5	2.5
CAD	1	1

Higher score = greater compliance.
Tied ranks are averaged.
CAD disposal has a lower rank due to possible water quality issues during construction and disposal. See Section 5.6.2 for discussion.

Table G-10—Disposal Option Ranking—Reduction in Toxicity, Mobility, and Volume

	Reduction in Toxicity	Reduction in Mobility	Reduction in Volume	Total
Upland	0	2	0	2
Nearshore	0	2	0	2
CAD	0	2	0	2

No disposal option reduces the toxicity or volume of contaminants in the environment. All options were assumed to be equally effective in reducing contaminant mobility.

Table G-11—Disposal Option Ranking—Short-Term Effectiveness

	Human Exposure	Worker Safety	Water Quality Impacts	Short-Term Habitat Loss	Duration	Total
Upland	1	1	3	3	1	9
Nearshore	3	3	2	2	2	12
CAD	2	2	1	1	3	9

Higher score = greater short-term effectiveness.
See Section 5.6.4 for discussion of assumptions.

Table G-12—Disposal Option Ranking—Long-Term Effectiveness

	Reliability of Remedy	Monitoring/ Maintenance Necessary	Adequacy of Institutional Controls	Total
Upland	3	3	2	8
Nearshore	1.5	2	3	6.5
CAD	1.5	1	1	3.5

Higher score = greater long-term effectiveness.
Tied scores are averaged.
See Section 5.6.5 for discussion of assumptions used in scoring.

Table G-13—Disposal Option Ranking—Implementability[a]

	Ease of Construction	Reliability of Technology	Monitoring Effectiveness	Availability of Site	Impacts to Fisheries	Time to Complete	Total
Upland	1	3	3	2	3	1	13
Nearshore	3	2	2	2	1	2	12
CAD	2	1	1	2	2	3	11

a) Administrative difficulties associated with siting were not distinguishable at this time.

Table G-14—Disposal Option Ranking—Cost

	Cost	Total
Upland	1	1
Nearshore	2	2
CAD	3	3

Higher score = less cost.

APPENDIX H

ALTERNATIVE-SPECIFIC RISK CALCULATIONS

Equations and Parameters

Fish and Shellfish Consumption Exposure Scenario Parameters		Exposure via Fish Consumption				Exposure via Shellfish Consumption			
Parameter	Parameter Description	Adult RME	Adult CTE	Child RME	Child CTE	Adult RME	Adult CTE	Child RME	Child CTE
c(fish)	concentration of contaminant in fish (ug/kg)	Chemical Specific							
IR	human daily ingestion rate of fish (g/day)	15.96	1.05	0.465	0.465	91.56	8.05	8.61	0.18
EF	human exposure frequency to scenario involving consumption of fish (days/yr)	175	175	175	175	175	175	175	175
ED	human exposure duration to scenario involving consumption of fish (years)	24	24	6	6	24	24	6	6
f(PS)	fraction of fish consumed that are obtained from Puget Sound (unitless)	0.21	0.21	0.21	0.21	0.67	0.67	0.67	0.67
f(species)	fraction of types fish/shellfish species consumed that are available at the site (unitless)	1	1	1	1	0.49	0.34	0.49	0.34
f(utilization)	fraction the site represents of total sites utilized by individuals in Puget Sound to harvest fish/shellfish (unitless)	1	1	1	1	1	1	1	1
BW	body weight of person (kg)	70	70	15	15	70	70	15	15
ATcancer	averaging time over which carcinogenic exposure should be considered--usually considered as a lifetime (years)	70	70	NA	NA	70	70	NA	NA
ATnoncancer	averaging time over which noncarcinogenic exposure should be considered--ususally considered as equal to the exposure duration (years)	24	24	6	6	24	24	6	6
RfDo	oral noncancer reference dose considered an exposure threshold (mg/kg-day)	Chemical Specific							
CSFo	oral cancer slope factor expressing carcinogenic toxicity of contaminant (kg-day/mg)	Chemical Specific							
HQ	hazard quotient expressing a ratio of exposure to the reference dose (unitless)	Chemical Specific							
CR	incremental cancer risk expressing probability of developing cancer over a lifetime from given exposure (unitless)	Chemical Specific							
THQ	target hazard quotient--predetermined value not to be exceeded (unitless)	1	1	1	1	1	1	1	1
TCR	target cancer risk--predetermined value not to be exceeded (unitless)	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
CF1	converts chem conc in fish from ug to mg (mg/ug)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	0.001	0.001	0.001	0.001
CF2	converts ingestion rate from g to kg (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	0.001	0.001	0.001	0.001
CF3	converts avg time from years to days (days/yr)	365	365	365	365	365	365	365	365

Sediment/Tissue Concentration Parameters			
Parameter	Parameter Description	Fish Value	Shellfish Value
c(sediment)	concentration of contaminant in sediment (ug/kg-DW)	chem spec	chem spec
c(fish)	concentration of contaminant in fish (ug/kg)	chem spec	chem spec
f(lipid)	fraction of lipid in fish (unitless)	0.017	0.0026
BSAF	biota sediment accumulation factor [(ug-contam/g-lipid)/(ug-contam/g-OC)] for transfer of contaminant from sediment to fish	chem spec	chem spec
foc	fraction of organic carbon in the sediment (unitless)	0.0183	0.0183

Equations for calculating risk

$$HQ = \frac{c(fish) \times IR \times EF \times ED \times f(PS) \times f(species) \times f(utliz) \times CF1 \times CF2}{BW \times ATnoncancer \times CF3 \times RfDo}$$

$$CR = \frac{c(fish) \times IRtwa \times EF \times (EDa+EDc) \times f(PS) \times f(species) \times f(utliz) \times CF1 \times CF2 \times CSFo}{BWtwa \times ATcancer \times CF3}$$

$$c(fish) = \frac{c(sed) \times f(lipid) \times BSAF}{foc}$$

Equations for calculating risk-based concentrations

$$RBC(fish) = \frac{THQ \times BW \times ATnoncancer \times CF3 \times RfDo}{IR \times EF \times ED \times f(PS) \times f(species) \times f(utliz) \times CF1 \times CF2}$$

$$RBC(fish) = \frac{TCR \times BWtwa \times ATcancer \times CF3}{IRtwa \times EF \times (EDc+EDa) \times f(PS) \times f(species) \times f(utliz) \times CF1 \times CF2 \times CSFo}$$

$$RBC(sed) = \frac{foc \times RBC(fish)}{f(lipid) \times BSAF}$$

Time-weighted average values over total exposure duration

$$IRtwa = \frac{(IRadult \times EDadult) + (IRchild \times EDchild)}{(EDchild + EDadult)}$$

$$BWtwa = \frac{(BWadult \times EDadult) + (BWchild \times EDchild)}{(EDchild + EDadult)}$$

SUMMARY INTAKE FACTORS						
	Fish			Shellfish		
	Cancer	Adult Noncancer	Child Noncancer	Cancer	Adult Noncancer	Child Noncancer
RME	9.41E-09	2.30E-08	3.12E-09	8.57E-08	2.06E-07	9.03E-08
CTE	6.82E-10	1.51E-09	3.12E-09	5.14E-09	1.26E-08	1.31E-09

NOTE: *HQ=(c(fish)*SIF)/RfDo*   *RBC(fish)=(THQ*RfDo)/SIF*

*CR=c(fish)*SIF*CSFo*   *RBC(fish)=TCR/(SIF*CSFo)*

INVERSE SUMMARY INTAKE FACTORS						
	Fish			Shellfish		
	Cancer	Adult Noncancer	Child Noncancer	Cancer	Adult Noncancer	Child Noncancer
RME	1.06E+08	4.36E+07	3.20E+08	1.17E+07	4.86E+06	1.11E+07
CTE	1.47E+09	6.62E+08	3.20E+08	1.95E+08	7.96E+07	7.63E+08

Residual Risks from RME Fish and Shellfish Consumption For Background

Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Risk at background										
			Background Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
			Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	1.25E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	4.05E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	7.11E+01	NA	NA	NA	NA	4.88E-04	2.14E-04	NA	4.88E-04	2.14E-04
Total B(a)P equivalent		7.30E+00	NA	3.52E+01	NA	NA	NA	2.20E-05	NA	NA	2.20E-05	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	*2.71E+01*	*NA*	*NA*	*NA*	*1.70E-06*	*NA*	*NA*	*1.70E-06*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	*3.20E+01*	*NA*	*NA*	*NA*	*2.00E-08*	*NA*	*NA*	*2.00E-08*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	*2.72E+01*	*NA*	*NA*	*NA*	*1.70E-06*	*NA*	*NA*	*1.70E-06*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	*1.15E+01*	*NA*	*NA*	*NA*	*7.19E-08*	*NA*	*NA*	*7.19E-08*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	*2.52E+01*	*NA*	*NA*	*NA*	*1.58E-05*	*NA*	*NA*	*1.58E-05*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	*1.25E+01*	*NA*	*NA*	*NA*	*7.81E-07*	*NA*	*NA*	*7.81E-07*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	*3.16E+00*	*NA*	*NA*	*NA*	*1.98E-06*	*NA*	*NA*	*1.98E-06*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	1.22E+02	1.87E+01	2.30E-06	1.40E-01	1.91E-02	3.21E-06	1.93E-01	8.46E-02	5.51E-06	3.33E-01	1.04E-01
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	9.66E-04	1.48E-04	1.42E-06	NA	NA	1.97E-06	NA	NA	3.39E-06	NA	NA
TOTAL PAH RISKS					*0.00E+00*	*0.00E+00*	*0.00E+00*	*2.20E-05*	*4.88E-04*	*2.14E-04*	*2.20E-05*	*4.88E-04*	*2.14E-04*
TOTAL PCB RISKS					*2.30E-06*	*1.40E-01*	*1.91E-02*	*3.21E-06*	*1.93E-01*	*8.46E-02*	*5.51E-06*	*3.33E-01*	*1.04E-01*
TOTAL DIOXIN RISKS					*1.42E-06*	*NA*	*NA*	*1.97E-06*	*NA*	*NA*	*3.39E-06*	*NA*	*NA*
TOTAL RISKS					3.72E-06	1.40E-01	1.91E-02	2.72E-05	1.93E-01	8.48E-02	3.09E-05	3.34E-01	1.04E-01
TOTAL RISKS W/OUT PCBS					1.42E-06	0.00E+00	0.00E+00	2.40E-05	4.88E-04	2.14E-04	2.54E-05	4.88E-04	2.14E-04

Residual Risks from CTE Fish and Shellfish Consumption For Background

			Risk at background										
			Background Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	1.2E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	4.1E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	7.1E+01	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	3.5E+01	NA	NA	NA	1.4E-06	NA	NA	1.4E-06	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	2.7E+01	*NA*	*NA*	*NA*	*1.1E-07*	*NA*	*NA*	*1.1E-07*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	3.2E+01	*NA*	*NA*	*NA*	*1.2E-09*	*NA*	*NA*	*1.2E-09*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	2.7E+01	*NA*	*NA*	*NA*	*1.1E-07*	*NA*	*NA*	*1.1E-07*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	1.1E+01	*NA*	*NA*	*NA*	*4.5E-09*	*NA*	*NA*	*4.5E-09*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	2.5E+01	*NA*	*NA*	*NA*	*9.8E-07*	*NA*	*NA*	*9.8E-07*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	1.2E+01	*NA*	*NA*	*NA*	*4.8E-08*	*NA*	*NA*	*4.8E-08*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	3.2E+00	*NA*	*NA*	*NA*	*1.2E-07*	*NA*	*NA*	*1.2E-07*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	122	19	1.7E-07	0.0	0.0	2.0E-07	0.0	0.0	3.7E-07	0.0	0.0
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0	0	1.0E-07	NA	NA	1.2E-07	NA	NA	2.3E-07	NA	NA
TOTAL PAH RISKS					*0E+0*	*0*	*0*	*1E-6*	*0*	*0*	*1E-6*	*0*	*0*
TOTAL PCB RISKS					*2E-7*	*0*	*0*	*2E-7*	*0*	*0*	*4E-7*	*0*	*0*
TOTAL DIOXIN RISKS					*1E-7*	*NA*	*NA*	*1E-7*	*NA*	*NA*	*2E-7*	*NA*	*NA*
TOTAL RISKS					**1E-7**	**0**	**0**	**1E-6**	**0**	**0**	**2E-6**	**0**	**0**
TOTAL RISKS W/OUT PCBS					**1E-7**	**0**	**0**	**1E-6**	**0**	**0**	**2E-6**	**0**	**0**

Residual Risks from RME Fish and Shellfish Consumption For Alternative 2

Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Residual risk following cleanup										
			Residual Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
			Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	39	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	292	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	205	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	162	NA	NA	NA	1.0E-04	NA	NA	1.0E-04	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	86	*NA*	*NA*	*NA*	*5.4E-06*	*NA*	*NA*	*5.4E-06*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	151	*NA*	*NA*	*NA*	*9.5E-08*	*NA*	*NA*	*9.5E-08*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	194	*NA*	*NA*	*NA*	*1.2E-05*	*NA*	*NA*	*1.2E-05*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	194	*NA*	*NA*	*NA*	*1.2E-06*	*NA*	*NA*	*1.2E-06*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	162	*NA*	*NA*	*NA*	*1.0E-04*	*NA*	*NA*	*1.0E-04*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	37	*NA*	*NA*	*NA*	*2.3E-06*	*NA*	*NA*	*2.3E-06*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	29	*NA*	*NA*	*NA*	*1.8E-05*	*NA*	*NA*	*1.8E-05*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	2285	350	4.3E-05	2.6	0.4	6.0E-05	3.6	1.6	1.0E-04	6.2	1.9
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0.01	0.0010	1.0E-05	NA	NA	1.4E-05	NA	NA	2.4E-05	NA	NA
TOTAL PAH RISKS					*0E+0*	*0*	*0*	*1E-4*	*0*	*0*	*1E-4*	*0*	*0*
TOTAL PCB RISKS					*4E-5*	*3*	*0*	*6E-5*	*4*	*2*	*1E-4*	*6*	*2*
TOTAL DIOXIN RISKS					*1E-5*	*NA*	*NA*	*1E-5*	*NA*	*NA*	*2E-5*	*NA*	*NA*
TOTAL RISKS					**5E-5**	**3**	**0**	**2E-4**	**4**	**2**	**2E-4**	**6**	**2**
TOTAL RISKS W/OUT PCBS					**1E-5**	**0**	**0**	**1E-4**	**0**	**0**	**1E-4**	**0**	**0**

Residual Risks from CTE Fish and Shellfish Consumption For Alternative 2

			Residual risk following cleanup										
			Residual Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	2.7E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	1.8E+02	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	1.7E+02	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	1.1E+02	NA	NA	NA	4.2E-06	NA	NA	4.2E-06	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	6.2E+01	*NA*	*NA*	*NA*	*2.4E-07*	*NA*	*NA*	*2.4E-07*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	1.0E+02	*NA*	*NA*	*NA*	*4.1E-09*	*NA*	*NA*	*4.1E-09*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	1.4E+02	*NA*	*NA*	*NA*	*5.3E-07*	*NA*	*NA*	*5.3E-07*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	1.1E+02	*NA*	*NA*	*NA*	*4.2E-08*	*NA*	*NA*	*4.2E-08*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	9.8E+01	*NA*	*NA*	*NA*	*3.8E-06*	*NA*	*NA*	*3.8E-06*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	2.7E+01	*NA*	*NA*	*NA*	*1.1E-07*	*NA*	*NA*	*1.1E-07*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	1.6E+01	*NA*	*NA*	*NA*	*6.3E-07*	*NA*	*NA*	*6.3E-07*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	1959	300	2.7E-06	0.1	0.3	3.2E-06	0.2	0.0	5.9E-06	0.3	0.3
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0	0	3.1E-07	NA	NA	3.7E-07	NA	NA	6.8E-07	NA	NA
TOTAL PAH RISKS					*0E+0*	*0*	*0*	*4E-6*	*0*	*0*	*4E-6*	*0*	*0*
TOTAL PCB RISKS					*3E-6*	*0*	*0*	*3E-6*	*0*	*0*	*6E-6*	*0*	*0*
TOTAL DIOXIN RISKS					*3E-7*	*NA*	*NA*	*4E-7*	*NA*	*NA*	*7E-7*	*NA*	*NA*
TOTAL RISKS					**3E-7**	**0**	**0**	**5E-6**	**0**	**0**	**5E-6**	**0**	**0**
TOTAL RISKS W/OUT PCBS					**3E-7**	**0**	**0**	**5E-6**	**0**	**0**	**5E-6**	**0**	**0**

Residual Risks from RME Fish and Shellfish Consumption For Alternative 3A

Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Residual risk following cleanup										
			Residual Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
			Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	12	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	41	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	71	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	35	NA	NA	NA	2.2E-05	NA	NA	2.2E-05	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	27	*NA*	*NA*	*NA*	*1.7E-06*	*NA*	*NA*	*1.7E-06*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	32	*NA*	*NA*	*NA*	*2.0E-08*	*NA*	*NA*	*2.0E-08*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	27	*NA*	*NA*	*NA*	*1.7E-06*	*NA*	*NA*	*1.7E-06*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	11	*NA*	*NA*	*NA*	*7.2E-08*	*NA*	*NA*	*7.2E-08*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	25	*NA*	*NA*	*NA*	*1.6E-05*	*NA*	*NA*	*1.6E-05*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	12	*NA*	*NA*	*NA*	*7.8E-07*	*NA*	*NA*	*7.8E-07*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	3	*NA*	*NA*	*NA*	*2.0E-06*	*NA*	*NA*	*2.0E-06*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	122	19	2.3E-06	0.1	0.0	3.2E-06	0.2	0.1	5.5E-06	0.3	0.1
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0.00	0.0001	1.4E-06	NA	NA	2.0E-06	NA	NA	3.4E-06	NA	NA
TOTAL PAH RISKS					*0E+0*	*0*	*0*	*2E-5*	*0*	*0*	*2E-5*	*0*	*0*
TOTAL PCB RISKS					*2E-6*	*0*	*0*	*3E-6*	*0*	*0*	*6E-6*	*0*	*0*
TOTAL DIOXIN RISKS					*1E-6*	*NA*	*NA*	*2E-6*	*NA*	*NA*	*3E-6*	*NA*	*NA*
TOTAL RISKS					**4E-6**	**0**	**0**	**3E-5**	**0**	**0**	**3E-5**	**0**	**0**
TOTAL RISKS W/OUT PCBS					**1E-6**	**0**	**0**	**2E-5**	**0**	**0**	**3E-5**	**0**	**0**

Residual Risks from CTE Fish and Shellfish Consumption For Alternative 3A

Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Residual risk following cleanup: Residual Concentrations (ug/kg) Fish Tissue	Shellfish Tissue	Fish Lifetime CR	Fish Adult HQ	Fish Child HQ	Shellfish Lifetime CR	Shellfish Adult HQ	Shellfish Child HQ	Total (Fish and Shellfish) Lifetime CR	Total (Fish and Shellfish) Adult HQ	Total (Fish and Shellfish) Child HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	1.2E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	3.8E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	6.8E+01	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	3.5E+01	NA	NA	NA	1.4E-06	NA	NA	1.4E-06	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	2.5E+01	*NA*	*NA*	*NA*	*9.9E-08*	*NA*	*NA*	*9.9E-08*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	3.1E+01	*NA*	*NA*	*NA*	*1.2E-09*	*NA*	*NA*	*1.2E-09*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	2.8E+01	*NA*	*NA*	*NA*	*1.1E-07*	*NA*	*NA*	*1.1E-07*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	1.2E+01	*NA*	*NA*	*NA*	*4.6E-09*	*NA*	*NA*	*4.6E-09*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	2.5E+01	*NA*	*NA*	*NA*	*9.6E-07*	*NA*	*NA*	*9.6E-07*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	1.2E+01	*NA*	*NA*	*NA*	*4.8E-08*	*NA*	*NA*	*4.8E-08*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	3.3E+00	*NA*	*NA*	*NA*	*1.3E-07*	*NA*	*NA*	*1.3E-07*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	128	20	1.7E-07	0.0	0.0	2.1E-07	0.0	0.0	3.8E-07	0.0	0.0
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0	0	1.2E-07	NA	NA	1.4E-07	NA	NA	2.7E-07	NA	NA
TOTAL PAH RISKS					*0E+0*	*0*	*0*	*1E-6*	*0*	*0*	*1E-6*	*0*	*0*
TOTAL PCB RISKS					*2E-7*	*0*	*0*	*2E-7*	*0*	*0*	*4E-7*	*0*	*0*
TOTAL DIOXIN RISKS					*1E-7*	*NA*	*NA*	*1E-7*	*NA*	*NA*	*3E-7*	*NA*	*NA*
TOTAL RISKS					**1E-7**	**0**	**0**	**2E-6**	**0**	**0**	**2E-6**	**0**	**0**
TOTAL RISKS W/OUT PCBS					**1E-7**	**0**	**0**	**2E-6**	**0**	**0**	**2E-6**	**0**	**0**

Residual Risks from RME Fish and Shellfish Consumption For Alternative 3B

			Residual risk following cleanup										
			Residual Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	22	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	91	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	178	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	69	NA	NA	NA	4.3E-05	NA	NA	4.3E-05	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	40	*NA*	*NA*	*NA*	*2.5E-06*	*NA*	*NA*	*2.5E-06*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	65	*NA*	*NA*	*NA*	*4.1E-08*	*NA*	*NA*	*4.1E-08*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	73	*NA*	*NA*	*NA*	*4.5E-06*	*NA*	*NA*	*4.5E-06*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	29	*NA*	*NA*	*NA*	*1.8E-07*	*NA*	*NA*	*1.8E-07*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	48	*NA*	*NA*	*NA*	*3.0E-05*	*NA*	*NA*	*3.0E-05*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	22	*NA*	*NA*	*NA*	*1.4E-06*	*NA*	*NA*	*1.4E-06*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	7	*NA*	*NA*	*NA*	*4.3E-06*	*NA*	*NA*	*4.3E-06*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	546	79	1.0E-05	0.6	0.1	1.4E-05	0.8	0.4	2.4E-05	1.4	0.4
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0.01	0.0010	9.6E-06	NA	NA	1.3E-05	NA	NA	2.3E-05	NA	NA
TOTAL PAH RISKS					*0.0E+00*	*0E+0*	*0*	*0*	*1E-3*	*0*	*0*	*1E-3*	*0*
TOTAL PCB RISKS					*1.0E-05*	*6E-1*	*0*	*0*	*8E-1*	*0*	*0*	*1E+0*	*0*
TOTAL DIOXIN RISKS					*9.6E-06*	*NA*	*NA*	*0*	*NA*	*NA*	*0*	*NA*	*NA*
TOTAL RISKS					**2.0E-05**	**6E-1**	**0**	**0**	**8E-1**	**0**	**0**	**1E+0**	**0**
TOTAL RISKS W/OUT PCBS					**0**	**0E+0**	**0**	**0**	**1E-3**	**0**	**0**	**1E-3**	**0**

Residual Risks from CTE Fish and Shellfish Consumption For Alternative 3B

			Residual risk following cleanup										
			Residual Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	1.5E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	6.2E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	1.1E+02	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	4.9E+01	NA	NA	NA	1.9E-06	NA	NA	1.9E-06	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	3.3E+01	*NA*	*NA*	*NA*	*1.3E-07*	*NA*	*NA*	*1.3E-07*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	4.7E+01	*NA*	*NA*	*NA*	*1.8E-09*	*NA*	*NA*	*1.8E-09*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	5.1E+01	*NA*	*NA*	*NA*	*2.0E-07*	*NA*	*NA*	*2.0E-07*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	1.7E+01	*NA*	*NA*	*NA*	*6.6E-09*	*NA*	*NA*	*6.6E-09*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	3.4E+01	*NA*	*NA*	*NA*	*1.3E-06*	*NA*	*NA*	*1.3E-06*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	1.6E+01	*NA*	*NA*	*NA*	*6.0E-08*	*NA*	*NA*	*6.0E-08*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	4.2E+00	*NA*	*NA*	*NA*	*1.6E-07*	*NA*	*NA*	*1.6E-07*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	283	43	3.9E-07	0.0	0.0	4.6E-07	0.0	0.0	8.4E-07	0.0	0.0
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0	0	3.0E-07	NA	NA	3.6E-07	NA	NA	6.6E-07	NA	NA
TOTAL PAH RISKS					*0.0E+00*	*0E+0*	*0*	*0*	*5E-5*	*0*	*0*	*5E-5*	*0*
TOTAL PCB RISKS					*3.9E-07*	*2E-2*	*0*	*0*	*3E-2*	*0*	*0*	*5E-2*	*0*
TOTAL DIOXIN RISKS					*3.0E-07*	*NA*	*NA*	*0*	*NA*	*NA*	*0*	*NA*	*NA*
TOTAL RISKS					**3.0E-07**	**0E+0**	**0**	**0**	**5E-5**	**0**	**0**	**5E-5**	**0**
TOTAL RISKS W/OUT PCBS					**0**	**0E+0**	**0**	**0**	**5E-5**	**0**	**0**	**5E-5**	**0**

Residual Risks from RME Fish and Shellfish Consumption For Alternative 4A

			Residual risk following cleanup										
			Residual Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	36	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	81	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	140	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	86	NA	NA	NA	5.4E-05	NA	NA	5.4E-05	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	70	*NA*	*NA*	*NA*	*4.4E-06*	*NA*	*NA*	*4.4E-06*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	76	*NA*	*NA*	*NA*	*4.7E-08*	*NA*	*NA*	*4.7E-08*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	173	*NA*	*NA*	*NA*	*1.1E-05*	*NA*	*NA*	*1.1E-05*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	173	*NA*	*NA*	*NA*	*1.1E-06*	*NA*	*NA*	*1.1E-06*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	86	*NA*	*NA*	*NA*	*5.4E-05*	*NA*	*NA*	*5.4E-05*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	32	*NA*	*NA*	*NA*	*2.0E-06*	*NA*	*NA*	*2.0E-06*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	12	*NA*	*NA*	*NA*	*7.8E-06*	*NA*	*NA*	*7.8E-06*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	297	45	5.6E-06	0.3	0.0	7.8E-06	0.5	0.2	1.3E-05	0.8	0.3
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0.00	0.0001	1.4E-06	NA	NA	2.0E-06	NA	NA	3.4E-06	NA	NA
TOTAL PAH RISKS					*0E+0*	*0*	*0*	*5E-5*	*0*	*0*	*5E-5*	*0*	*0*
TOTAL PCB RISKS					*6E-6*	*0*	*0*	*8E-6*	*0*	*0*	*1E-5*	*1*	*0*
TOTAL DIOXIN RISKS					*1E-6*	*NA*	*NA*	*2E-6*	*NA*	*NA*	*3E-6*	*NA*	*NA*
TOTAL RISKS					**7E-6**	**0**	**0**	**6E-5**	**0**	**0**	**7E-5**	**1**	**0**
TOTAL RISKS W/OUT PCBS					**1E-6**	**0**	**0**	**6E-5**	**0**	**0**	**6E-5**	**0**	**0**

Residual Risks from CTE Fish and Shellfish Consumption For Alternative 4A

			Residual risk following cleanup										
			Residual Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	2.1E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	5.9E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	1.0E+02	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	5.6E+01	NA	NA	NA	2.2E-06	NA	NA	2.2E-06	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	4.3E+01	*NA*	*NA*	*NA*	*1.7E-07*	*NA*	*NA*	*1.7E-07*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	5.0E+01	*NA*	*NA*	*NA*	*2.0E-09*	*NA*	*NA*	*2.0E-09*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	8.6E+01	*NA*	*NA*	*NA*	*3.3E-07*	*NA*	*NA*	*3.3E-07*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	7.1E+01	*NA*	*NA*	*NA*	*2.8E-08*	*NA*	*NA*	*2.8E-08*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	4.8E+01	*NA*	*NA*	*NA*	*1.9E-06*	*NA*	*NA*	*1.9E-06*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	2.0E+01	*NA*	*NA*	*NA*	*7.7E-08*	*NA*	*NA*	*7.7E-08*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	6.6E+00	*NA*	*NA*	*NA*	*2.6E-07*	*NA*	*NA*	*2.6E-07*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	201	30	2.7E-07	0.0	0.0	3.2E-07	0.0	0.0	6.0E-07	0.0	0.0
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0	0	1.2E-07	NA	NA	1.5E-07	NA	NA	2.7E-07	NA	NA
TOTAL PAH RISKS					*0.0E+00*	*0.0*	*0.0*	*2.2E-06*	*0.0*	*0.0*	*2.2E-06*	*0.0*	*0.0*
TOTAL PCB RISKS					*2.7E-07*	*0.0*	*0.0*	*3.2E-07*	*0.0*	*0.0*	*6.0E-07*	*0.0*	*0.0*
TOTAL DIOXIN RISKS					*1.2E-07*	*NA*	*NA*	*1.5E-07*	*NA*	*NA*	*2.7E-07*	*NA*	*NA*
TOTAL RISKS					**1.2E-07**	**0.0**	**0.0**	**2.3E-06**	**0.0**	**0.0**	**2.4E-06**	**0.0**	**0.0**
TOTAL RISKS W/OUT PCBS					**1E-7**	**0**	**0**	**2E-6**	**0**	**0**	**2E-6**	**0**	**0**

Residual Risks from RME Fish and Shellfish Consumption For Alternative 4B

			Residual risk following cleanup										
					Fish			Shellfish			Total (Fish and Shellfish)		
			Residual Concentrations (ug/kg)		Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	39	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	292	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	178	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	162	NA	NA	NA	1.0E-04	NA	NA	1.0E-04	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	86	*NA*	*NA*	*NA*	*5.4E-06*	*NA*	*NA*	*5.4E-06*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	151	*NA*	*NA*	*NA*	*9.5E-08*	*NA*	*NA*	*9.5E-08*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	194	*NA*	*NA*	*NA*	*1.2E-05*	*NA*	*NA*	*1.2E-05*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	194	*NA*	*NA*	*NA*	*1.2E-06*	*NA*	*NA*	*1.2E-06*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	162	*NA*	*NA*	*NA*	*1.0E-04*	*NA*	*NA*	*1.0E-04*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	37	*NA*	*NA*	*NA*	*2.3E-06*	*NA*	*NA*	*2.3E-06*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	29	*NA*	*NA*	*NA*	*1.8E-05*	*NA*	*NA*	*1.8E-05*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	2285	350	4.3E-05	2.6	0.4	6.0E-05	3.6	1.6	1.0E-04	6.2	1.9
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0.01	0.0012	1.2E-05	NA	NA	1.6E-05	NA	NA	2.8E-05	NA	NA
TOTAL PAH RISKS					*0E+0*	*0*	*0*	*1E-4*	*0*	*0*	*1E-4*	*0*	*0*
TOTAL PCB RISKS					*4E-5*	*3*	*0*	*6E-5*	*4*	*2*	*1E-4*	*6*	*2*
TOTAL DIOXIN RISKS					*1E-5*	*NA*	*NA*	*2E-5*	*NA*	*NA*	*3E-5*	*NA*	*NA*
TOTAL RISKS					**5E-5**	**3**	**0**	**2E-4**	**4**	**2**	**2E-4**	**6**	**2**
TOTAL RISKS W/OUT PCBS					**1E-5**	**0**	**0**	**1E-4**	**0**	**0**	**1E-4**	**0**	**0**

Residual Risks from CTE Fish and Shellfish Consumption For Alternative 4B														
			Residual risk following cleanup											
			Residual Concentrations (ug/kg)		Fish			Shellfish			Total (Fish and Shellfish)		
					Lifetime	Adult	Child	Lifetime	Adult	Child	Lifetime	Adult	Child
Chemical	RfDo (mg/kg-day)	CSFo (kg-day/mg)	Fish Tissue	Shellfish Tissue	CR	HQ	HQ	CR	HQ	HQ	CR	HQ	HQ
Polycyclic Aromatic Hydrocarbons													
Benzo(g,h,i)perylene			NA	2.4E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene			NA	1.5E+02	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	3.00E-02		NA	1.5E+02	NA	NA	NA	NA	0.0	0.0	NA	0.0	0.0
Total B(a)P equivalent		7.30E+00	NA	9.2E+01	NA	NA	NA	3.6E-06	NA	NA	3.6E-06	NA	NA
Benzo(a)anthracene		*7.30E-01*	*NA*	5.4E+01	*NA*	*NA*	*NA*	*2.1E-07*	*NA*	*NA*	*2.1E-07*	*NA*	*NA*
Chrysene		*7.30E-03*	*NA*	8.9E+01	*NA*	*NA*	*NA*	*3.5E-09*	*NA*	*NA*	*3.5E-09*	*NA*	*NA*
Benzo(b)fluoranthene		*7.30E-01*	*NA*	1.1E+02	*NA*	*NA*	*NA*	*4.3E-07*	*NA*	*NA*	*4.3E-07*	*NA*	*NA*
Benzo(k)fluoranthene		*7.30E-02*	*NA*	8.5E+01	*NA*	*NA*	*NA*	*3.3E-08*	*NA*	*NA*	*3.3E-08*	*NA*	*NA*
Benzo(a)pyrene		*7.30E+00*	*NA*	8.1E+01	*NA*	*NA*	*NA*	*3.1E-06*	*NA*	*NA*	*3.1E-06*	*NA*	*NA*
Indeno(1,2,3-cd)pyrene		*7.30E-01*	*NA*	2.4E+01	*NA*	*NA*	*NA*	*9.3E-08*	*NA*	*NA*	*9.3E-08*	*NA*	*NA*
Dibenz(a,h)anthracene		*7.30E+00*	*NA*	1.3E+01	*NA*	*NA*	*NA*	*5.1E-07*	*NA*	*NA*	*5.1E-07*	*NA*	*NA*
Polychlorinated Biphenyls													
Total PCB	2.00E-05	2.00E+00	1504	227	2.1E-06	0.1	0.2	2.4E-06	0.1	0.0	4.5E-06	0.3	0.2
Dioxins/Furans													
Total 2,3,7,8-TCDD(Equiv)		1.56E+05	0	0	4.5E-07	NA	NA	5.2E-07	NA	NA	9.7E-07	NA	NA
TOTAL PAH RISKS					*0E+0*	*0*	*0*	*4E-6*	*0*	*0*	*4E-6*	*0*	*0*
TOTAL PCB RISKS					*2E-6*	*0*	*0*	*2E-6*	*0*	*0*	*4E-6*	*0*	*0*
TOTAL DIOXIN RISKS					*4E-7*	*NA*	*NA*	*5E-7*	*NA*	*NA*	*1E-6*	*NA*	*NA*
TOTAL RISKS					**4E-7**	**0**	**0**	**4E-6**	**0**	**0**	**5E-6**	**0**	**0**
TOTAL RISKS W/OUT PCBS					**4E-7**	**0**	**0**	**4E-6**	**0**	**0**	**5E-6**	**0**	**0**

APPENDIX I

RESPONSES TO COMMENTS ON RI/FS TECHNICAL MEMORANDA

APPENDIX I

RESPONSE TO COMMENTS ON RI/FS TECHNICAL MEMORANDA

Corps of Engineers Comments on Pacific Sound Resources Remedial Investigation Report and Technical Memoranda (April 1998) Specific Comments on Engineering Considerations on "Sediment Feasibility Study, Alternative Development, Technical Memorandum 2, Pacific Sound Resources Marine Sediments Unit, Seattle, Washington," dated April, 1998.

1. **Page 3, para. 2.2.2.** Dredging at this site presents several significant technical challenges. First, the bottom slopes offshore of the site are as steep as 1 vertical (V) on 3 horizontal (H). The potential effect of removing 400,000 cy of material on slope stability probably will need to be addressed. Removal of fine contaminated sediments with a clam shell dredge may result in an unacceptable level of resuspended material, and this method of dredging probably will not be acceptable. Since readily available hydraulic dredges are limited to working at depths of about 60' or less, dredging contaminated material from the area between -60' MLLW and -200' MLLW may not be feasible.

   Response: An analysis of the bathymetry indicates slopes are generally less than 18-21% (70% < 18%). Slope stability near the shoreline is a concern. Therefore, the FS recommends that area near the shoreline be capped and any dredging occur further out and away from the slope at a distance where integrity will not be jeopardized. Hydraulic dredging is the dredge method used for costing purposes in the FS. Dredging at depths of 200 feet will need to be done with a specialty hydraulic dredge.

2. **Page 3, para. 2.2.3.** Placement of the capping material probably will have to be by hydraulic methods, (wash-off or pump-out) to minimize the resuspension of contaminated bottom sediments. The capping volumes shown for all the capping alternatives assume a uniform cap thickness of 3'. Controlling the placement of material in water depths of 30' to 200' may be difficult, and significant variations in the cap thickness could occur. In addition, monitoring the cap thickness will be extremely difficult, particularly in depths of 200'. For these reasons, a design thickness of 5' to 6' may be required to assure that a minimum thickness of 3' has been achieved. The 15% contingency for "loss during placement" may be appropriate for material with a very low percent of fines, but sufficient quantities of this type of dredged material may not be readily available. A loss of 25%, or higher, would allow for the placement of dredged material from a wider range of sources. Assuming an average cap thickness of 5' and a loss of 25% would result in an increase in the required volume of capping material by a factor of 2, or a total requirement of about 850,000 cy.

   Response: An evaluation was made to determine which areas of the cap need to be placed using the wash-off/hydraulic method. Due to the elevated contaminant concentrations, the hydraulic placement methods were assumed for all areas of capping. For estimating cap *volumes in the FS, it is assumed that at depths less than 100 feet, a 3-foot cap is adequate and 15% loss of capping material during placement occurs. At depths greater than 100 feet, a 5-foot cap will be the target to ensure a minimum of 3 feet is achieved and a 25% loss of capping material is assumed.*

3. **Page 6, para. 3.1.1.** A comprehensive geotechnical study probably would be required to assure that the nearshore slope will support the dike and the enclosed disposal site.

   Response: For the initial evaluation in the FS, a preliminary geotechnical evaluation was performed to indicate the static stability of the site (See FS Appendix C). For design, a more in depth study would need to be performed if this disposal method is chosen.

Comments on Section 404(b)(1) ARAR Compliance.

General Comments:

4. Since a 404 process normally requires a binary permit decision (i.e., a permit is either issued or denied), the information must be presented in very definitive terms. The RI was not intended to meet the needs for a 404 evaluation. As such, the decision process which guided the RI and the Technical Memos is not as clearly documented as a 404 evaluation would require. For example, Tech. Memo 1 eliminated upland disposal as a general response action because it was not 'cost-effective.' Upland disposal is exorbitantly expensive and a common sense approach would eliminate it from further consideration. However, the 404 process would require that the Government define the factors of 'cost-effectiveness,' and also discuss why a site is screened out from further analysis. That is, how much is too much to achieve the project purpose? We believe this can be done relatively easily, but it still must be documented as to how the government made a decision regarding the efficacy of a potential alternative. In the absence of a clear demonstration as to why an upland site is rejected, the Government would have to retain such a site for consideration.

   Response: Upland disposal has been retained for evaluation in the FS (see FS Section 3.333) and a cost comparison with other disposal alternatives is provided (see FS Section 5.4 and 5.6.7). The preferred alternative will be selected based on a variety of factors. For alternatives with equivalent degrees of environmental protection and feasibility, cost may be a deciding factor, but at this time the FS does not include criteria for cost-effectiveness.

5. The 404 process is totally driven by the project purpose statement. As such, the Government should develop a precise (and short) project purpose statement prior to actually evaluating alternatives. The project purpose sets the stage for developing project evaluation criteria and developing a reasonable range of alternatives. The alternatives are then tested against the evaluation criteria. The end result is the selection of the least environmentally damaging, practicable alternative available to meet the project purpose.

   Response: A project purpose statement has been developed in consultation with the Corps and other reviewing agencies for inclusion in the FS (See FS Section 1.2).

6. As a side note, the documents do not state why the RAOs changed from the RI to Tech. Memo 1. There is also no explanation as to why the Government settled on the two specific clean-up criteria (CSL, SQS). Although it may be intuitive to the reader, the 404 evaluation will require an explanation of how the Government got from one point to the other. This should not require much work; it should just be documentation of the thought process.

   Response: The Washington Sediment Management Standards (SMS) were used to gauge the magnitude of releases from the PSR site and the potential for injury to benthic communities exposed to such releases. As such, they are the numeric criteria used to determine if the more qualitative RAOs were achieved. In addition, the SMS allows a range of cleanup criteria to be evaluated for a project. The overall goal is to achieve the Sediment Quality Standards, if this proves to be technically feasible and provides quantifiable benefit for the costs incurred. At a minimum, the Cleanup Screening Level is to be achieved (if feasible). See Section 2.2.1 for how these standards were used to evaluate the site, Section 2.5 of the FS for a discussion of RAOs, and Appendix J for selection of cleanup level..

7. After the development of the project purpose, the government should develop what factors must be met to achieve the project purpose. This is usually done in terms of costs, technology, and logistics. However, whatever factor the Government determines to be necessary to meet the project purpose, it must provide a definition of that factor. Again, if cost-effectiveness is a factor that will determine an alternative's efficacy, then the Government must document how they determined cost-effectiveness. The fact that an alternative may simply cost 'more' is not a reason for the Government to reject it's [*sic*] ability to meet the project purpose (that is, to be 'practicable'). If an alternative is rejected due to costs, the Government must demonstrate that the alternative was prohibitively expensive, and therefore not practicable.

   Response: This is done to the extent possible.

8. Each alternative is tested against the project criteria to determine it's [*sic*] ability to meet the project purpose. We have found it is helpful to develop the criteria as binary standards; an alternative meets a given criteria or it does not. All criteria must also be met if an alternative is to satisfy the project purpose. This structured process provides the Government with a very clear record of it's [*sic*] decision process.

   Response: This is done to the extent possible in the FS.

9. We scanned the RI, but did not notice any specific detail on how the Government determined that natural attenuation could not meet project needs. This will have to be described for the No-Action alternative for the 404(b)(1) evaluation.

   Response: The potential for natural recovery was discussed in Section 3.3.2.8 of the RI. In addition, the results of this discussion are added to the No Action Alternative evaluation (See FS Section 5.3.1.1).

Specific Comments

10. For PSR, we found at least three slightly different statements that could serve, or be incorporated into, a project purpose for the remedial action. The RI has Remedial Action Objectives (RAO) listed on page 1-2 (paragraph 1.2). Tech. Memo 1 also has a more precise statement of specific RAOs on page 2 (paragraph 3.1.1). Lastly, Tech. Memo 1 also provides very specific Cleanup Criteria on page 6 (paragraph 3.2.1). Any one of these could serve as a project purpose. We believe the RAO in the RI is probably the best fit as a project purpose. It also has the added benefit in that it does not hold the Government to any numerical/testable standard that the Government may change it's [*sic*] mind about later.

    Response: A project purpose statement (objectives) is provided in the FS (See FS Section 1.2).

11. There is not much specific detail from the RI and Tech. Memos that can be used for the 404 evaluation. This is no flaw with the data, it is more the fact that the 404(b)(1) evaluation is very impact specific. Most of the required information describes the actual project and it's [sic] specific environmental impacts (e.g., specific source of sediments, time of construction, specific impacts related to construction, expected water quality impacts, etc.). We have attached an annotated outline with more detail on where specific information either is or when it needs to be developed.

    Response: As much of this information as possible has been incorporated into the FS.

From: Ann R. Uhrich at NPS-EN; these are Eric Nelson's (and one of the Corps [NPS-EN] geotechnical engineers) comments

12. If one dredges 400,000 cy close to shore on a steep slope, it may cause the slope above the dredging to become unstable and tend to slump. The potential for this would appropriately be quantified via a geotechnical study anytime in the process from feasibility out through plans and specs. Eric [Nelson] suggested doing it sooner than later, as he is dubious that dredging will ultimately be a viable option (based on BPJ from years of experience) for this particular project.

    Response: For purposes of the FS, capping has been determined as necessary for all alternatives along the shoreline so as not to impact the stability of the shoreline.

13. Regarding resuspension, he [Eric Nelson] was referring here generally to the fact that clam shell dredging of fine contaminated sediments could resuspend them for long enough that it could have at least short-term affects on water quality. He also advises that placement of sediments during disposal could affect water quality at the PSR site, and suggests you speak with Ellie Hale, as EPA has already been through a disposal decision process at Eagle Harbor (where the decision was made to hydraulically place dredged sediments in areas where minimizing the resuspension of bottom sediments was a design goal).

Response: Clamshell dredging is not the most likely technique to use for dredging at this site. In the FS, specialty hydraulic dredging has been assumed for costing purposes.

14. At the PSR site, a bottom dump type of disposal in 200' of water on a steep slope probably would carry sediment hundreds (if not thousands) of feet down slope, in Eric's opinion. An extensive numerical model analysis would be required to provide estimates of suspended material concentrations and extent of transport (he is assuming that design goals would include not wanting to resuspend contaminated sediments much, if at all, and would include wanting disposal or capping material to be rather precisely placed and then have it stay in place rather than migrate).

    Response: The FS does not assume bottom dumping contaminated sediment into a CAD site for disposal. For the FS CAD disposal option, clamshell placement will be assumed, although this has significant re-suspension potential. This is pointed out in the FS (See FS Section 5.4.1.4).

15. A 5' to 6' cap is not something typically done, and the reason he suggested it here (under the impression that the 3' cap was the desired ultimate design cap thickness) was solely because in his view one could not rely on existing sediment placement methods to accurately locate 3' of clean sediment-evenly- over a large area at PSR, given the relatively steep slopes. So the extra placement was to assure that all areas would have a -minimum- of 3' cap in place when all was said and done.

    While tremie tubes are used in some instances to place material more precisely, his feeling in this case is that it would have to be a very large one (perhaps 10' or more in diameter) to efficiently move large amounts of material but at this size it would make the device logistically impracticable (it would be very hard to move around such a large tube, and even ones this large can become plugged up). FYI, Eric discussed the capping in place option directly with Greg Stuesse of Weston on May 28th, along with monitoring the thickness of placed material. He suggests that EPA and Weston may find a couple of published papers on this topic of some help, and I will forward them to you.

    Response: Noted. Tremie tubes are not assumed. The additional thickness of cap needed to ensure a 3-foot thickness is incorporated in the FS (See FS Section 4.1.2).

16. An issue that is important for all upland or nearshore confined aquatic disposal facilities (CDFs) is that of dike stability. This would also be true of subtidal (deeper) CADs. Due to the slope on this site, Eric believes that a geotechnical study would be necessary to assure dike stability. According to our geological engineers, a typical geotechnical study for this type of project would consist of a field exploration phase and an office analysis phase.

    The field investigation would consist of exploration borings at selected intervals along the proposed containment dike alignment. In-situ testing of the soils would consist of Standard Penetration Tests (SPT) and/or Dutch Cone type testing to determine relative density of the subsurface soils. Soil samples would be taken and laboratory testing would be performed to determine soil parameters/characteristics for design. Typical laboratory tests would consist of strength testing and consolidation testing.

The design analysis phase would evaluate the stability of the containment dike during and after construction, the slope stability of the dredged slopes in relation to the containment dike, and settlement of containment dike during and after construction.

For a project like this, the geotechnical investigation should be conducted when an alignment for the containment dike is agreed upon. Any subsequent significant changes in the dike alignment would require additional geotechnical studies. Typically, this type of geotechnical study would be conducted during the plans and specifications phase of a project, however geotechnical studies can be conducted during the feasibility study phase depending on what information is available at the proposed site.

Again, the whole purpose of this would be to assure that once material is placed in a CDF or deeper water CAD it stays in place in essence for perpetuity (excluding major seismic events which could affect any remedial action).

Response: In the FS, a preliminary geotechnical evaluation has been completed to determine conceptually if a nearshore disposal option warrants further investigation. If this option initially appears feasible and the decision is made to proceed with nearshore disposal, then a more rigorous geotechnical study would need to be performed.

Review Comments: Tamara Allen, Environmental Specialist, Aquatic Resources Division, Department of Natural Resources

General Comments

17. DNR has recently begun drafting criteria regarding cleanup and restoration of state-owned aquatic lands. These criteria support DNR's long-standing assertion that state-owned aquatic lands will not remain a repository or be used as a future repository for contaminated sediments unless such a decision is based on a bay-wide planning effort that has shown this use to be in the best interest of the resources and the public. As managers of state-owned aquatic lands, DNR would like, in the context of an ecosystem management approach, to return resource function and ensure resource protection and sustainability for the long-term benefit of the resources and the public. The following draft criteria help to frame these goals:

- Aquatic lands are too valuable and scarce to be used as dumps;
- all disposal must be clearly in the long-term best interest of the public;
- disposal decisions will be made in the context of the whole bay and the department's long-term stewardship goals for publicly-owned aquatic lands;
- truly hazardous materials will not be allowed to remain or be placed on state-owned aquatic lands. Sediments that exceed Minimum Cleanup Levels (MCULs) under the Washington State Sediment Management Standards or fail Toxic Criteria Leachability Procedures or US Army Corps of Engineers' leachability procedures are considered hazardous sediments that

exceed the standards. Where these exist on state-owned lands, but due to lack of technical feasibility cannot be treated or removed, they must be isolated from the rest of the environment. As soon as is technically feasible, the material must be treated or removed;

- investments in navigation and commerce along harbor areas and waterways will be maintained to provide for economic growth and to avoid development elsewhere; and
- full costs will be evaluated, including habitat restoration.

Evaluation points associated with the criteria include:

- Consistency with the department's state land use plans;
- a clear net gain in habitat area and function;
- protection and creation of critical habitats for listed or candidate threatened or endangered species;
- efficient use of state-owned aquatic land material for beneficial uses as defined in the Puget Sound Dredged Disposal Analysis guidelines;
- disposal alternatives that prepare for rebuilding large blocks of habitat areas;
- disposal alternatives that provide for acquisitions and/or development of strategic habitat areas;
- avoidance and minimization of impacts and compensatory mitigation measures; and
- the best rate of return on the investment of state natural resources.

DNR is in the beginning stages of implementation of these draft criteria in conjunction with a number of bay-wide planning efforts, including Elliott Bay. I [Tamara Allen, DNR] look forward to working with EPA and the other reviewing agencies on the integration of DNR criteria with the group's additional goals and objectives for the PSR MSU. The following discussion offers initial comments on the technical memoranda in the context of the preceding criteria.

SPECIFIC COMMENTS

Technical Memorandum 1

18. **Page 2, 3.1.1 Remedial Action Objectives**: Although restoration goals would not change the general response actions associated with the RAOs as defined, a discussion needs to be initiated regarding restoration objectives for this site to allow a more complete evaluation of the general response actions. There needs to be a more thorough analysis of habitat potential and the approach should be precautionary in order to ensure that any cleanup planning efforts do not preclude potential restoration activities. Given the potential salmon listings in Puget Sound under the Endangered Species Act (ESA), the proposed cleanup and restoration activities for the PSR MSU should be evaluated through an ESA consultation.

Response: A restoration (or habitat enhancement) component has been added to the nearshore disposal alternatives.

19. **Page 3, Treatment**: I understand from our conversations that some additional investigation into *in situ* treatment options is being undertaken. *In situ* treatment is consistent with both DNR's draft criteria and with the potential stability issues associated with sediment removal at the site (discussed in subsequent sections). I appreciate the effort to evaluate *in situ* treatment further and look forward to continued discussions of possible innovative treatment technologies.

    Response: To date, no in situ treatment technologies for sediment are available. The papers and projects referenced by DNR include studies of biodegradation rates for PAHs and other organics under anaerobic conditions and ex-situ treatment pilot studies. For this reason, in situ treatment technologies could not be used in developing alternatives.

20. **Page 6, Technology Screening**: Although an EPA guidance document for FS preparation is referenced in a previous report section, it would be helpful to include more detailed definitions of the three criteria being used to screen applicable technologies. Previous sections referred to these criteria as: effectiveness, implementability, and cost; and protectiveness, cost and technical feasibility. However, in this section, the criteria are referred to as: technical difficulties, administrative concerns, or excessive costs. The correlation between administrative concerns and the criteria as presented in earlier report sections is not clear to me; it seems as though administrative concerns are equivalent criteria to effectiveness and protectiveness.

    Response: These sections have been revised for consistency in the FS. Information on what each of the 7 CERCLA criteria consists of is provided in the FS (See FS Section 5.2). The criteria used to screen technologies are: (1) overall protection of human health and the environment, (2) implementability, and (3) cost.

21. **Page 7, Containment Technology Screening**: As the text indicates, the thickness of a cap needs to ensure long-term isolation of the contaminants. Depending on design considerations, in order to adequately contain the contaminated material and possibly provide habitat, a cap may need to be thicker than the approximated 3-foot thickness discussed in a previous report section. As we have discussed, I would also like the potential for optimizing cap design to augment microbial biodegradation to be assessed. The text also indicates that a small portion of the cap may be impacted by anchoring.

    Response: A 3-foot thick cap is used in the FS to isolate the sediments because of the potential for bioturbation. Based on recent research by the University of Washington and others, biodegradation of the PAHs is not significant under anaerobic conditions and is not an option for sediment remediation in that biodegradation of PAHs will likely never achieve cleanup levels.

As DNR criteria state, it is important that the site-specific planning efforts are developed in the context of a bay-wide plan that includes discussions of land use and commerce and navigation issues, as well as cleanup and habitat restoration. The initial steps of a bay-wide planning effort were undertaken by a number of federal, state, and local agencies and tribal governments and can be found in the *Development of an Aquatic Management Plan for Elliott Bay and the Duwamish Estuary: A Study* which was prepared by PTI Environmental Services for the Puget Sound Water Quality Authority in 1993. As part of DNR's planning efforts for Elliott Bay, this study will be revisited in light of current conditions (particularly the proposed salmon listings), and I would like to encourage continued discussion of cleanup and restoration at the PSR MSU in the context of a larger planning effort for Elliott Bay.

The summary table at the end of the text (Table 1) provides cost estimates for some of the technologies, including the capping option. It would be helpful if the text included a discussion of these cost estimates. For example, it is not clear if the cost estimates include long-term monitoring and maintenance costs. DNR criteria ask that full costs be evaluated, including costs associated with habitat restoration. The full costs for the capping option should also include and estimate for accurate placement and monitoring of cap material at depths of approximately -250 feet MLLW which, as the text indicates, requires more effort; the goal is complete isolation of the contaminated material. And, finally, as the capping option is evaluated further, the full cost evaluation should include compensatory costs associated with the use of state-owned aquatic lands as a repository for contaminated sediments.

Response: EPA believes the recommended alternative is compatible with bay-wide planning and will minimize interference with future plans. The costs shown in the memorandum were used for screening and were primarily the costs to construct or treat the sediment (i.e., these costs were not all inclusive). Costs for the set of remedial alternatives addressed in the FS include all costs associated with that alternative including monitoring and mitigation costs to the extent possible (See Appendix F of the FS). EPA agrees that compensatory cost should be a component of cost comparison and looks forward to further discussion of this issue.

22. **Pages 7-8, Removal Technology Screening**: As discussed previously, DNR encourages the removal of all contaminated material from state-owned aquatic lands. However, as we have also discussed, the main concern that DNR has associated with the removal option at the PSR site, is slope stability. A large part of the sediment contamination at the PSR site is located on a delta front. Removal of this material off the delta front has the potential to cause slope failures. Site-specific geotechnical information needs to be acquired and evaluated in order to better assess the removal option.

    Response: A preliminary geotechnical evaluation has been conducted as part of the FS that indicates removal of material could be completed without slope failure (See FS Appendix C).

23. It is not clear from the discussion of the option to dredge materials exceeding cleanup screening levels (CSL) if the total volume in exceedance will be removed. There is discussion of a small percentage of material in exceedance of CSL at depths that may be prohibitively deep for dredging; however, the discussion also implies complete removal. All

materials in exceedance of CSL should be removed unless technically infeasible, and the full costs associated with complete removal should be evaluated.

Response: The dredging alternative has been reconfigured such that contaminated material at depths too deep to dredge(>-200' MLLW) will be capped (See FS Section 4.2.2.2).

24. DNR's criteria ask for the removal of all truly hazardous materials, as defined by MCUL exceedances, from state-owned aquatic land. This is a minimum criteria. It is important to note that DNR's long-term stewardship goals for state-owned aquatic lands include returning resources to their full function and protecting their long-term health. Removal of material to SQS is most consistent with these goals. Because of this and notwithstanding the potential stability issues, I would like to request further analysis of the option to dredge all sediments that exceed SQS.

    Response: Dredging all sediment that exceeds SQS would consume all of the available nearshore disposal capacity off of Lockheed assuming the facility were filled and capped to 15 feet above MLLW. CAD disposal sites available to handle this capacity have not been located. Costs for this remedy can range from $35 to $80 million, depending upon the disposal option. Therefore, this option was not included.

25. **Pages 9-10, Disposal Site Technology Screening, Nearshore Disposal**: As we have discussed, one of the main concerns associated with the nearshore disposal option is slope stability. The proposal is not only to remove material off the front of the delta in close proximity to the area on which disposal will occur but also to place that material in a facility that is designed out to the break in slope at the top of the delta. This combination of activities creates what could potentially be significant slope stability issues. We have discussed the fact that if a nearshore option is to be evaluated, the footprint for the facility must be moved inshore approximately 500 feet. In addition, site-specific geotechnical information needs to be evaluated in order to better assess stability issues associated with material removal and placement in a nearshore facility. A second geological consideration that will need to be addressed for the nearshore option is the close proximity of the proposed facility to the Seattle Fault. This is a factor not only in evaluating the suitability of this site for a nearshore fill but also in design considerations for the facility.

    Assuming the geotechnical issues are resolved, the idea of submerging part of the nearshore facility to create habitat is relatively consistent with DNR criteria. However, we would also like to see the creation of larger blocks of habitat in the context of a bay-wide planning effort. And, also in the bay-wide context, cleanup activities at the Lockheed site and other cleanup sites in the bay, as well as any land use considerations at the Lockheed site, should be coordinated with the nearshore proposal.

    After geotechnical considerations, if the nearshore facility is still proposed on state-owned aquatic lands, DNR criteria ask that the disposal decision clearly be in the long-term best interest of the resources and the public and that the decision is made in the context of the whole bay. And, as discussed under the capping option, an evaluation of full costs must be completed, including compensatory costs for use of state-owned aquatic lands as a repository for contaminated materials.

Response: The concept for the nearshore disposal option has been evaluated in the FS with respect to geotechnical concerns. A preliminary geotechnical evaluation has been completed to assess the technical feasibility of the nearshore disposal site and its stability concerns (See FS Appendix C.) If this option is selected, further geotechnical studies will need to be completed to support design of the disposal site. For the purpose of the FS, the nearshore disposal option will be located back from the delta front such that geotechnical stability is ensured. Moving it back 500 feet is not reasonable given that the whole area is only 800 to 1,000 feet wide. Moving it back this far would eliminate all its disposal capacity.

Potential habitat development on the face of the berm has been discussed in the FS (See FS Section 4.3.2 and Figure 4-15). Sloping the fill area itself is technically not feasible given that the material has little internal strength to withstand sloping.

The nearshore disposal option has been spatially integrated with the Lockheed cleanup plans. This integration is discussed in the FS. (See FS Section 4.3.2)

27. **Pages 9-10, Disposal Site Technology Screening, CAD**: DNR encourages your proposal to work with the Corps and the agencies participating in the Multi-User Disposal Site (MUDS) workgroup to identify areas in the vicinity of Elliott Bay that might serve as potential CAD sites. DNR is an active participant in this process and will be evaluating the identification of sites in the context of the aforementioned criteria.

    Response: The Corps was queried regarding potential options for CAD sites locations. Potential CAD sites are shown and evaluated in the FS (See FS Section 4.3.1 and Figure 4-12).

28. **Pages 9-10, Disposal Site Technology Screening, Upland Disposal**: Assuming the geotechnical issues associated with the removal of material from the delta slope are resolved, DNR requests that the upland disposal option be retained for further consideration, primarily because it is seen as a potentially viable option that would ensure removal of contaminated material from state-owned aquatic lands without subsequent disposal onto other state-owned aquatic lands.

    Response: Upland disposal is included as a disposal option in the FS (See FS Section 3.3.3.3 and 4.3.3).

29. **Page 10, Treatment Technology Screening**: Please see my previous comments (Page 3, Treatment)

    Response: Noted

Technical Memorandum 2

30. I do not have additional specific comments associated with the second technical memorandum, beyond those discussed in the context of the first memorandum. The only comment that I do have is an offer of assistance in determining availability of clean sediment. Ted Benson, DNR's Puget Sound Dredged Disposal Analysis Coordinator, can be reached at (360)902-1083 for information regarding sediment availability.

    Response: The Corps has provided information with respect to upcoming dredging projects in the next 7 years and estimates of capping sediment availability have been developed. This information is included in the FS (See Section 4.1.2.1 and Table 4-2).

From Dr. Robert Kayen, Research Civil Engineer, United States Department of the Interior, Geological Survey.

Subject: Sediment Feasibility Study for the PSR Site

31. I read *Technical Memorandum 1: Sediment Feasibility Study Technology Identification and Screening* and *Technical Memorandum 2: Sediment Feasibility Study Alternative Development*, written for the PSR site. Although I cannot address issues of the cost-benefit or relative effectiveness of the competing technologies, I reviewed the document from the perspective of its technical merits given the geologic setting and concerns of seismic stability.

    Neither memorandum addresses the serious issue of seismic stability of a placed cap or berm/retention structure. The two primary issues regarding seismic loading of the slope are: 1) are the native deposits susceptible to liquefaction, inertially driven displacement or flow failure and 2) does the placement of a surcharge (1-2m thin cap or 35' bermed retention structure increase the susceptibility of the slope to liquefaction, inertially driven displacement or flow failure.

    Site specific analysis of the liquefaction potential of the native sediment is needed prior to selection of remediation technology as these deposits are generally loose late-Holocene silt/sand non-cohesive materials (Hart/Crowser Report). Proximity to known active faults like the Seattle fault warrant detailed investigation of this hazard. Our studies indicate that some native sediment in the region immediately offshore PSR are susceptible to liquefaction during earthquakes and could potentially runout into deeper water in a flow failure (Kayen, Barnhardt, and Palmer, in press). Placement of a 1-2 m cap on these materials probably would not have a significant impact on the seismic performance of the native sediment. The placed cap may be susceptible to liquefaction and flow failure, and may need to be rebuilt following an earthquake.

    The placement of a 10-meter berm and sediment retention facility will, with certainty, increase the seismic-induced stresses in the underlying native deposits and may elevate the effective overburden stress-normalized seismic shear stresses (ratio of earthquake stresses to burial stress) for these deposits. A site-specific analysis of the impact of the retention facility on the liquefaction and flow-failure potential of the underlying native sediment is warranted.

The seismic stability of the offshore may be considerably reduced if the structure is built to +10' MLLW and the underlying native sediment is shaken prior to reaching equilibrium under the new surcharge: Such equilibrium could take decades or more to achieve depending on the amount of interbedding of fine-grained layers in the native deposits and the likely drainage pathways. Drainage could be accelerated using wicks, although there are significant issues regarding the influence of wicks on upward migration of contaminants. An analysis of the rate of compaction and full dissipation of excess pore pressures of the native sediment under the load of a 10m berm is warranted.

The retention facility may, itself, be prone to liquefaction and flow failure if the berm and retained materials are loosely placed. Design considerations must address a minimum-threshold compaction effort for the berm to resist liquefaction, if it is to be built of sand.

Response: The seismic stability of this site is of concern. If nearshore disposal is selected as the preferred disposal option, further evaluation will need to be completed such that the likely failure under a given magnitude of earthquake can be determined. Then, EPA and other agencies will make a risk management decision whether this disposal option meets their risk criteria or whether the cost of cleanup after failure offsets the disadvantages of other disposal options and is worth the risk.

32. Other Considerations: Biological activity of benthic organisms may result in "tilling" of a placed cap by bioturbation (diffusion through biological mixing). Such mixing could contaminate the cap and bring contaminant to the surface. Benthic organisms could bioaccumulate contaminants and serve as base-level introducers of contaminant to the food-chain. An analysis of the potential rates of bioturbation should be done by a marine biologist specializing in biodiffusion processes. Critical questions are 1) is a sandy cap considerably different from the native sediment in texture and organic content to be a preferable host-environment for benthic organisms? 2) what is the tilling depth of benthic organisms local to Elliott Bay? 3) are the contaminants likely to accumulate in benthic animal tissue?

Response: If benthic organisms are exposed to site-related contaminants, these chemicals would accumulate in their tissues (benthic invertebrates do not readily metabolize PAHs) and serve as a pathway for exposure of other aquatic organisms. However, bioturbation is not expected to have significant influence on the confining nature of a cap. The selection of a 3-foot cap is, in part, designed to address bioturbation. For the majority of soft-bottom habitats in Puget Sound, the biologically active zone is considered to be the top 10 cm (or less). The deepest burrowing organisms tend to be members of the stable communities that inhabit the very deep, fine-grained basins of Puget Sound (i.e., deeper than the PSR MSU). One exception is the ghost and mud shrimp, which inhabit finer-grained sediments in intertidal and shallow nearshore environments in inlets and bays. These organisms create burrows up to 2 to 3 feet below mudline (burrowing activity tends to be heaviest in the upper 18 to 20 inches of sediment). These species have not been documented at the site, but most sampling devices for benthic organisms do not necessarily capture these shrimp. However, their typical habitat is not present at the PSR site.

33. **Recommendations:**—The assessment of liquefaction and flow potential of the cap should be made through existing field methodologies (Cone Penetration Testing/Standard Penetration Testing, and textural analysis of sediment). The Washington Department of Natural Resources and Department of Transportation have these field capabilities and could be used to rapidly develop a dataset for liquefaction assessment by drilling/probing *onshore* near the waters-edge at the PSR-Lockheed sites. Offshore barge-based drilling and probing could then be used to complete an onshore-offshore tie of the data. Assessment of liquefaction-and flow failure-hazards should follow these efforts for both the offshore and onshore zones. An advantage of using an onshore-offshore drilling and probing program is that the native sediment onshore have already been loaded by a 'sediment retention facility' through the construction of the onshore PSR-Lockheed facilities, and so comparisons can be made between the seismic hazard potential of the native deposits offshore prior to modification and at a 'post-construction' site very similar to the proposed berm/retention environment in the same geologic environment.

    A marine biologist is needed to address concerns of benthic biodiffusion of contaminants through a cap.

    Response: It is EPA's understanding that DNR and the USGS are pursuing additional investigations regarding liquefaction and flow potential. As any results become available, EPA will incorporate this information into it's decision-making process. Please also see the response to the issue of bioturbation, above.

Glen R. St. Amant, Senior Sediment Specialist, - Muckleshoot Indian Tribe, Fisheries Department

Comments on the Draft Remedial Investigation Report

34. **Section 2.2.2. Biota. Page 2-11 (last paragraph) and 2-12 (first two lines).** Although this paragraph mentions that Chinook salmon are common in the vicinity of the Marine Sediment Unit (MSU), there is no mention of the proposal by National Marine Fisheries Service to list this species as threatened under the Endangered Species Act (ESA). Please incorporate this information. As a sidebar, you may want to consider mentioning how EPA plans to coordinate with this proposed ESA listing at this site, since this will be a requirement at PSR.

    Response: The proposed status for Chinook salmon was mentioned in Appendix K of the RI, under Federally Recognized Sensitive Species in the description of potential receptors. Also, this issue was addressed through project-specific criteria in the FS (Section 1.2).

35. **Section 3.3.2.5. Free-Phase and Dissolved Creosote Migration. Page 3-8. Last Sentence.** This sentence states that due to the depth of free-phase dense Non-Aqueous Phase Liquids (DNAPL) observed in the sand stringers, DNAPL is unlikely to surface through the sediment. Please explain this point further. Although depth is certainly a consideration in the likely fate of DNAPL transport, so is the deeply sloping offshore sediment bathymetry. Therefore, even if you[r] point remains the same, this issue could be clarified for the readers.

Response: A detailed description of the potential for DNAPL transport is included in the Upland RI (RETEC 1997).

36. Section 5.4. Areas of MSU Surface Sediment Exceeding Chemical Criteria. Page 5-5. Last Paragraph. This section discusses the approximate areal extent of PAH surface sediment contamination at the MSU. However, upon review of the data and Figure 5-14, it is evident that EPA has not delineated the PAH exceedance boundary at the northwest area of the site (specifically, the areas northwest of stations EB136, EB137, and EB144). Please explain how this information gap has and will influence EPA remedial decision making at the site. For example, it would seem that various risk characterization scenarios would change, depending upon the estimated areal extent of contamination. Therefore, the estimated protectiveness of differing remedial alternatives may also be affected by this lack of information. In addition, information on the extent of contamination at Station EB115 needs to be presented.

    Response: The northwestern boundary described above is characterized by low level SQS exceedances of only a few chemicals. Dibenzofuran is present at all three stations at concentrations ranging from 1.4 to 1.5 times the SQS. Acenaphthene is at two stations slightly above the SQS (1.1 times) and at the third stations at 1.4 times the SQS. Fluorene and naphthalene are present at one station each at their respective SQS criterion (i.e., 1.0 times). For the purposes of delineating the site boundary, EPA feels that these data are sufficient to delineate the site.

    Data for Station 115 are presented in the Appendix D of the RI.

37. **Section 6.3. Contaminant Selection. Page 6-2. Last Sentence in Paragraph.** This sentence states that PCBs and mercury were not evaluated, because the relationship to the upland wood-treating activities was not shown. However, i[t] also states that the areas of exceedance of these chemicals generally correspond to the PAH-contaminated areas. The Trustees are concerned with this approach. Chapter 5 of the RI points out that 60% of the PCB sampling stations exceeded SQS criteria and approximately 40% of the mercury sampling stations exceeded SQS criteria. Therefore, regardless of the source, these contaminants are present at levels of potential concern throughout the MSU. Since the PSR RI/FS process will rely on the basis of ecological and human health incremental risk reductions for determining the protectiveness of various remedial alternatives, the proposed decision not to evaluate PCB and mercury risks may skew the residual risks that will actually exist at the MSU following cleanup. Therefore, the Trustees strongly encourage EPA to incorporate PCB and mercury as contaminants of concern (COCs) in the MSU. Incorporation of PCBs and mercury as COCs would also necessitate an evaluation of the adequacy of source control for these contaminants on the proposed remedial method.

    Response: EPA will address the PCB and mercury exceedances within the PAH footprint in the MSU (See Figures 4-6 through 4-8, 4-10 and 4-11 of the FS). EPA believes that both mercury and PCBs represent historical sources. PCBs are believed to primarily have originated from the old Seattle Landfill via the Longfellow Creek overflow. The Port of Seattle has cleaned out the pipe and excavated sediments immediately in front of the outfall.

In addition, material from the landfill has been reconsolidated and confined within the upland facility as part of the redevelopment by the Port. The primary mercury sources are from the West Waterway and were transported to the MSU via longshore sediment transport processes.

38. **Section 6.6. Human Health Risk Characterization and Uncertainties. Page 6-6. Second Paragraph**. This paragraph summarizes (as detailed in appendix K) the two risk reduction scenarios considered for cleanup: 1) cleanup of sediments in the MSU above Sediment Management Standards (SMS) Cleanup Screening Levels (CSL), and 2) cleanup of sediments in the MSU above SMS Sediment Quality Standards (SQS). Upon review of your proposed remedial alternatives for this MSU, it appears that most proposed alternatives neither eliminate all CSL exceedance areas nor SQS exceedance areas. Therefore, the exercise of determining these incremental risk reduction scenarios does not seem to address your desired purpose of determining the protectiveness of various remedial alternatives. The Trustees would like EPA to revise their incremental risk reduction calculations to more accurately reflect different cleanup alternatives that will be retained for consideration in the FS. In addition, the previous comment on incorporation of PCB and mercury information should be included in this revised risk calculation.

    Response: The risk reductions associated with each are included in the FS (See FS Sections 5.3.2.1, 5.3.3.1, 5.3.4.1).

39. **Section 6.6. Human Health Risk Characterization and Uncertainties. Page 6-6. Third Paragraph**. This paragraph essentially states that either of the two general cleanup scenarios (cleanup to CSL or to SQS) fall short of the Washington Model Toxics Control Act (MTCA) risk management range, which is an ARAR. However, cleanup to SQS comes closer to this range. Please explain how EPA plans to incorporate this information into selection of a protective remedy. This issue is especially unclear since several cleanup alternatives proposed in the FS Technical Memoranda propose cleanup to the less protective CSL range or even only a portion of the CSL contamination in the MSU.

    Response: MTCA defers sediment cleanup to the SMS (WAC 173-204), which has no specific risk management range. All alternatives meet the risk range as specified in the NCP.

Comments on the PSR Sediment Feasibility Study Technology Identification and Screening Technical Memorandum 1.

40. **Section 3.1.1. Remedial Action Objectives. Page 2. First Bullet**. The risk range proposed is 1×10^{-4} to 1×10^{-6}. However, the MTCA (an ARAR) risk management range is 1×10^{-5} to 1×10^{-6}. Please change the proposed Remedial Action Objective to reflect the MTCA range.

    Response: The risk range 1×10^{-4} to 1×10^{-6} is specified in the NCP (40 CFR 300) and stated in the EPA CERCLA Guidance Documents. MTCA defers sediment cleanup to the SMS (WAC 173-204), which has no specific risk range.

41. **Section 3.2. Technology Screening. Pages 6-11.** The reason that certain technologies are proposed to be screened out do not seem to be consistently applied. For example, costs are used to screen out certain technologies without a discussion of the relative environmental/human health protectiveness (i.e., how well the Remedial Action Objectives are met) for those alternatives. Other alternatives are retained, but limited information on estimated costs or relative environmental protectiveness is given. This section should be revised to reflect a more consistent evaluation approach.

    Response: Two technologies were screened out. The two technologies were upland disposal and sediment treatment. Based on earlier comments, upland disposal will be retained and this section will be revised accordingly. Sediment treatment will still be eliminated based on technical feasibility issues. (See FS Section 3.4).

42. **Section 3.2.2. Containment Technology Screening. Page 7. Second Paragraph.** The first sentence of this paragraph states that capping is technically implementable at this site. Has EPA already evaluated the potential cap stability issues at this steeply sloping site? Has EPA already evaluated the efficacy of a cap to effectively isolate DNAPLs in the sediment? Whereas the Trustees do not object to retaining this technology for further evaluation, some of the major challenges could be identified in this paragraph.

    Response: These issues have been evaluated. The site has slopes generally less than 18%. Caps can be placed on slopes up to 25% with reasonable stability. The FS contains a thorough discussion of this issue (See Section 4.1.2 and 4.1.6 of the FS). There is no conclusive evidence that suggests DNAPL is present in the sediment off shore. However, if it was present, it would tend to have a downward migration potential. Placement of a 3-foot thick cap would prevent exposure to DNAPL impacted sediment if it exists.

43. **Section 3.2.3. Removal Technology Screening. Page 8. Last Paragraph.** This paragraph is extremely confusing. First of all, it seems that this section begins to develop remedial alternatives, in addition to the purpose of the Memo, which is to screen technologies. Perhaps much of this discussion should be moved to Tech. Memo 2. Regardless of where these discussions occur, please consider the following comments on the alternatives discussed in this paragraph. Dredging to SQS is proposed for no further consideration because of cost compared to capping. It is not clear that EPA has fully considered the costs of capping sediment on State-owned Aquatic Land. Has the EPA coordinated with the Washington State Department of Natural Resources on this issue? In addition, dredging to the CSL is proposed for further evaluation, based solely on cost. It would seem that a discussion of the ability of the proposals to achieve the Remedial Action Objectives would be warranted. Finally, a statement about the likely capacity of disposal facilities is made, without any supporting information.

    Response: The cost for capping on state-owned aquatic land is discussed in the FS to the extent possible (see also, response to Comment 2). Dredging to CSLs has been retained because the sediment is shallower and easier to dredge, it meets the RAOs, requires less precious disposal area and is significantly less expensive. Dredging to SQS has been *eliminated because of depth, the large disposal capacity required and cost. No Disposal sites have been identified that are large enough to handle 970,000 cy of sediment. The estimated maximum capacity of the PSR (Lockheed Nearshore Disposal Site is 900,000 cy. Use of this site to dispose of PSR sediments would leave no capacity to dispose of Lockheed's sediment. The CAD sites have a maximum capacity of 730,000 cy; which is less than the SQS volume. Approximately 15% (150,000 cy) of the SQS sediment is greater than 200 feet below MLLW and can't be dredged. Although cost was a factor in its elimination, it was only one of many.*

44. **Section 3.2.4. Disposal Site Technology Screening. Page 9. Second Paragraph**. The disposal site option discussed is proposed to fill up to the existing upland grade. Please consider options that would not be as disruptive to habitat, such as not constructing the entire facility to upland grade, but rather incorporating intertidal habitat features. In general, the Trustees do not encourage alternatives that involve filling of the marine environment, and the associated habitat loss, when other viable alternatives exist.

    Response: The nearshore disposal option in the FS addresses the concern of intertidal/shallow subtidal areas. Constructing the site such that the material inside the berm is intertidal would be technically very difficult due to the lack of strength in the dredged material and loss of disposal capacity. Intertidal areas have been incorporated into the outward face of the confining berm. (See FS Section 4.3.2 and Figure 4-15)

45. **Section 3.2.4. Disposal Site Technology Screening. Page 10. Third Full Paragraph.** Upland disposal is proposed not to be retained for further consideration, because of lack of available sites. However, no information on how this conclusion of site availability was made. In addition, conversations with the U.S. Army Corps of Engineers indicate that EPA was provided with some candidate sites. The Trustees strongly encourage EPA to retain upland disposal for additional consideration.

    Response: Upland disposal will be retained as a disposal option.

Comments on the PSR Sediment Feasibility Study Alternative Development Technical Memorandum 2.

46. **Section 2.1. Development of Alternatives. Page 1. Last Full Sentence**. This sentence states that alternatives were developed to be protective of human health and the environment as defined by the Washington SMS. However, the risk range incorporated into the SMS from MTCA for human health (1×10^{-5} to 1×10^{-6}) does not seem to be achieved under many of the alternatives (please refer to the RI, page 6-6). Please clarify this apparent contradiction.

    Response: MTCA defers sediment cleanup requirements to the SMS; there are no numerical human health risks in the SMS. The risk range used was that specified in the NCP (40 CFR 300) 1×10^{-4} to 1×10^{-6} due to lack of other specific risk guidance for sediment.

47. **Section 2.1. Development of Alternatives. Page 2. Last Sentence**. This sentence mentions that adequate source control measures will need to be employed, regardless of the

remedial alternative, to ensure remediation efficacy. The example given for source control is the placing of clean fill to extend the shoreline. The Trustees strongly encourage EPA to consider other source control measures that do not involve filling the marine environment or intertidal habitat areas.

Response: Areas near the shoreline are not amenable to dredging due to slope stability (See FS Section 4.1.7.2). Capping in these areas is the only option available, in addition to the No Action option.

48. **Section 4. Site-Specific Constraints Affecting Remedial Alternatives. Page 10.** Please add a bullet identifying that Tribal Treaty Fishing occurs within the MSU.

Response: This has been added in the FS (See FS Section 1.2).

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APPENDIX J

SELECTION OF SEDIMENT CLEANUP LEVEL

TECHNICAL MEMORANDUM

SELECTION OF A CLEANUP LEVEL FOR THE PACIFIC SOUND RESOURCES MARINE SEDIMENT UNIT

The minimum cleanup standard under the Washington State Sediment Management Standards (SMS) Rule has been selected as the trigger for active remediation of sediments within the Pacific Sound Resources (PSR) Marine Sediments Unit (MSU). An exception to the use of the minimum cleanup level (MCUL; equivalent to the cleanup screening level or CSL) is in the cleanup of PCBs in the nearshore environment. At those locations, PCB sediment concentrations exceeding the Sediment Quality Standard (SQS) will be included in the area to be remediated.

SUMMARY

The justification for selection of the MCUL for PAHs is as follows:

- No benthic community impacts were evident at the nine biological sampling stations based on the comparison of major taxa abundance at the site to reference conditions.
- Bioassay failures were noted, but were primarily for the amphipod bioassay and generally were within the minor adverse effects range.
- Biological samples were collected from within the MCUL/CSL chemical exceedance area where more severe effects were anticipated. Only minimal adverse impacts are predicted in remaining areas with sediment concentrations between the SQS and the MCUL/CSL.
- Cleanup of the area exceeding the MCUL/CSL chemical standards will address the area where adverse effects were observed.
- Cleanup to the MCUL/CSL addresses the areas where contaminated sediment has accumulated at depth and confines the greatest mass (approximately 96 percent) of contaminants.
- The majority of the sediments that will remain in place following cleanup (i.e., those that have chemical concentrations less than the MCUL/CSL) are in deep water and provide minimal exposure potential to fishers and recreational users of the bay.
- The moderately contaminated sediments that will remain following cleanup do not occur within the critical nearshore habitats used by juvenile salmonids.
- Mercury contamination will be addressed by cleanup of PAHs exceeding the MCUL/CSL chemical criteria.
- Human health risks are similar for remedial alternatives that achieve the MCUL/CSL versus the SQS*).*

- Use of the MCUL/CSL as the cleanup trigger will address sediments as a source of contamination to deeper, less contaminated sediments. All other sources of PAH contamination have been controlled to the degree that recontamination is unlikely.
- Cleanup costs to achieve the SQS were greater than 190 percent of the costs to achieve the CSL.

Justification for the selection of the SQS for PCBs in the nearshore environment is:

- The nearshore environment provides critical habitat for juvenile salmonids and their prey. Puget Sound chinook are currently proposed as a threatened species and will require restoration.
- Cleanup of PCBs in areas exceeding its SQS is cost effective because only minimal additional area will require remediation (i.e., PCBs co-occur with PAHs)

DISCUSSION

Selection of the MCUL as the cleanup level for PAHs was based on data collected as part of the remedial investigation (RI) and feasibility study (FS) that has been completed for the PSR MSU. During the RI, surface sediment samples were collected from 161 unique locations over 150 acres in Elliott Bay to delineate the nature and extent of the contamination in the vicinity of the PSR upland unit. Sample locations ranged in depth from -0.5 to -81 meters MLLW. Of those samples, 109 were analyzed for chemical or physical parameters (others were subjected to immunoassays or archived). At 17 locations, subsurface samples at 4-foot intervals up to 20 feet below mudline were analyzed for similar constituents. The subsurface samples were located within the area predicted by the USGS sub-bottom profiling data to be areas of significant accumulations of contaminated fill material that was a result of releases from the site (direct discharge of waste materials, dumping, spills, etc). Biological effects tests were conducted at nine locations in the area bordering the predicted footprint of the contaminated fill. Tests included amphipod mortality, echinoderm embryo abnormal development/mortality, and benthic community structure (based on major taxa abundance).

The results of the RI indicated that 47 acres exceeded SMS chemical CSLs for PAHs in surface sediments and 96 acres (inclusive of the CSL exceedance area) exceeded the more stringent SQS for these chemicals. Accumulations of contaminated sediment at depth appear to be primarily associated with the area identified by the USGS as potential fill north of the upland facility and a secondary discharge/disposal area north of Crowley Marine Services.

No benthic community effects were noted at any of the nine sampling locations. Larval abnormality/mortality in exceedance of the SQS was limited to one location (EB104). Amphipod mortality exceeded the CSL criterion at two locations (EB60 and EB87); five other locations exceeded the SQS criterion (EB67, EB77, EB80, EB85, and EB104). Stations EB49 and EB106 in the western portion of the site had no bioassay exceedances. Details of the evaluation are provided in Attachment 1.

The majority of the stations exhibiting SQS-level biological effects fell within the CSL chemical exceedance area. The range of chemical exceedances at the stations with SQS biological exceedances was 1.5 to 12.1 times the SQS chemical criteria, which tends to suggest that the chemical criteria over-predict the potential for biological effects at this site. However, the biological data were collected to support a ecological risk assessment, rather than boundary delineation. As a result, there are too few data to fully delineate cleanup areas based on biological data alone.

Under the SMS Rule, the cleanup of a site should result in an elimination of adverse effects to biological resources and significant health threats to humans. The SQS are considered the numerical values that correspond to this narrative goal. A site-specific cleanup standard is to be as close as practicable to the SQS, given consideration of environmental effects, feasibility and cost. Given site-specific factors, a cleanup level can be selected from within the range of the SQS at the time of cleanup (SQS_0, the most stringent standard) to the minimum cleanup level after 10 years of natural recovery ($MCUL_{10}$). Where natural recovery is not likely, the upper end of the range is restricted by the MCUL (to be achieved at the time of cleanup or $MCUL_0$). To date, three cleanup standards have been applied at sites in Puget Sound: the SQS_0, $MCUL_0$, and $MCUL_{10}$.

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ATTACHMENT 1

Evaluation of the bioassay data was based on the Washington State Sediment Management Standards, which requires comparison of site samples to reference samples. However, substitution of the planned reference station data was required due to reference area performance failures. Accordingly, the data were evaluated several ways. The first method compared the bioassay responses to those of the least impacted reference samples (Carr Inlet). Inclusion of this approach was based on a recommendation from Ecology's technical representative, after their review of the RI data. The second method involved use of the reference area performance criteria (25 percent mortality for amphipods and 30 percent combined abnormality and mortality for the echinoderm test) as the reference values. This second method was applied for the reason that this level of response is allowed at a reference site and would be considered to be within the range of an unimpacted population.

The MSU bioassay results, when compared to Carr Inlet, only showed a CSL level hit for amphipod mortality at one MSU station. No other bioassay failures occurred. The results are provided in Tables J-1 and J-2.

When compared to performance criteria, 7 of the 9 amphipod tests had significantly greater mortality than would be allowed at a reference site; 5 at an SQS-level and 2 at a CSL level. Only one echinoderm test had significantly higher effective mortality and was at an SQS-level with respect to the magnitude of effects. The results are provided in Tables J-1 and J-2. As part of the ecological risk assessment, the relationship between the magnitude of effects and chemical concentrations was examined; amphipod mortality did not appear to be a reliable predictor of where PAH concentrations were elevated (high mortalities occurred where few PAHs exceeded criteria at low levels [less than 2 times the SQS] and where many PAHs were highly elevated. Low mortalities occurred under the same scenarios). In contrast, the incidence of abnormalities in echinoderm larval development showed a strong relationship to the magnitude of PAHs.

The seven stations with the potential biological failures (SQS or CSL) based on comparison to performance criteria are located at the boundary of or within the area identified by the USGS as non-native sediments/potential fill. All but one sample is associated with CSL chemical exceedances in the surface sediments. The two stations passing all biological tests were associated with the discharge/disposal area north of Crowley Marine Services.

For the purposes of discussion, the comparison to performance criteria was retained because it represents a more protective approach than accepting the Carr Inlet results.

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Table J-1—Comparison of Amphipod Results to Carr Inlet and Reference Area Performance Criterion

Station	Amphipod								
		vs. Carr Ref				vs. SMS Ref			
	Average Mortality (%)	t-test P-Level	Exceeds SQS Criterion?	Exceeds CSL Criterion?	Overall SQS or CSL Hit	KW P-Level (vs. 25%)[b]	Exceeds SQS Criterion?	Exceeds CSL Criterion?	Overall SQS or CSL Hit
PSR MARINE SEDIMENT UNIT									
EB49	28	<0.329	No	No	--	<0.288	No[a]	No	--
EB60	61	<0.059	No[a]	No	--	<0.003	Yes	Yes	CSL
EB67	46	<0.213	No[a]	No	--	<0.003	Yes	No	SQS
EB77	51	<0.169	No[a]	No	--	<0.010	Yes	No	SQS
EB80	43	<0.304	No[a]	No	--	<0.047	Yes	No	SQS
EB85	51	<0.163	No[a]	No	--	<0.010	Yes	No	SQS
EB87	72	<0.022	Yes	Yes	CSL	<0.003	Yes	Yes	CSL
EB104	43	<0.283	No[a]	No	--	<0.045	Yes	No	SQS
EB106	37	<0.448	No[a]	No	--	<0.120	No	No	--
REFERENCE									
CARR	36	--	--	--	--	--	--	--	--
CARR SQS	36	--	--	--	--	--	--	--	--
CARR CSL	66	--	--	--	--	--	--	--	--
SMS REF	25	--	--	--	--	--	--	--	--
SMS REF SQS	25	--	--	--	--	--	--	--	--
SMS REF CSL	55	--	--	--	--	--	--	--	--

[a]Exceeds numeric criterion but not statistically significantly different from reference

[b]Non-parametric Kruskal-Wallis (KW) required in place of t-test as there is no variance associated with the substituted reference value

Table J- 2—Comparison of Echinoderm Results to Carr Inlet and Reference Area Performance Criteria

Station	Echinoderm								
		vs. Carr Ref				vs. SMS Ref			
	Effective Mortality (%)	t-test P-Level	Exceeds SQS Criterion?	Exceeds CSL Criterion?	Overall SQS or CSL Hit	KW P-Level (vs. 30%)[b]	Exceeds SQS Criterion?	Exceeds CSL Criterion?	Overall SQS or CSL Hit
PSR MARINE SEDIMENT UNIT									
EB49	10	<0.001	No	No	--	<0.001	No	No	--
EB60	10.8	<0.001	No	No	--	<0.001	No	No	--
EB67	28	<0.088	No	No	--	<0.008	No	No	--
EB77	13.1	<0.002	No	No	--	<0.008	No	No	--
EB80	21.1	<0.018	No	No	--	<0.209	No	No	--
EB85	31.7	<0.206	No	No	--	<0.209	No	No	--
EB87	41.3	<0.327	No	No	--	<0.053	No	No	--
EB104	49	<0.034	No	No	--	<0.001	Yes	No	SQS
EB106	16.7	<0.003	No	No	--	<0.008	No	No	--
REFERENCE									
CARR	37	--	--	--	--	--	--	--	--
CARR SQS	52	--	--	--	--	--	--	--	--
CARR CSL	67	--	--	--	--	--	--	--	--
SMS REF	30	--	--	--	--	--	--	--	--
SMS REF SQS	45	--	--	--	--	--	--	--	--
SMS REF CSL	60	--	--	--	--	--	--	--	--

[a]Exceeds numeric criterion but not statistically significantly different from reference

[b]Non-parametric Kruskal-Wallis (KW) required in place of t-test as there is no variance associated with the substituted reference value